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Assessment of Incineration As A Treatment Method for Liquid Organic Hazardous Wastes

Summary and Conclusions

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ASSESSMENT OF INCINERATION AS A TREATMENT METHOD FOR LIQUID ORGANIC HAZARDOUS WASTES:

SUMMARY AND CONCLUSIONS

March 1985

U.S. Environmental Protection Agency
Office of Policy, Planning and Evaluation
Washington, D.C. 20460

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 25 1985

OFFICE OF
POLICY, PLANNING AND EVALUATION

MEMORANDUM

SUBJECT: Final Report of the OPPE Incineration Study

FROM: Milton Russell Milton Russell
Assistant Administrator for
Office of Policy, Planning and Evaluation

TO: A. James Barnes
Acting Deputy Administrator

The Agency-wide assessment of incineration that former Deputy Administrator Alvin Alm requested is complete. It presents a summary of information currently available on the advantages and disadvantages of incineration as a commercial treatment option for managing liquid organic hazardous wastes and the issues associated with its use. It also describes the Agency's regulatory approach to controlling the incinerator burn itself and the handling of hazardous wastes from the generator or storage site to the burn site. The central focus is the detailed comparison of land-based and ocean-based incineration systems. Liquid organic hazardous wastes are chosen as a basis for comparison because they represent the type of waste that can be treated by both systems.

The regulation of incineration by EPA is complicated because it occurs in three different programs under three different statutes. My office was given the task of conducting this study because of our unique perspective as the Administrator's policy office, and because we do not directly administer any of these regulatory programs.

The purpose of the study is to provide better information for EPA decision making. A primary objective is to support informed Agency decision making on ocean incineration as the Office of Water develops its regulations and research plans, and begins to consider permit applications. The study will also assist in implementation of other aspects of EPA's hazardous waste management program.

The study provides an assessment based upon a snapshot of public concerns and scientific and market data available in the summer and fall of 1984. Although some new data were developed during these months, time and resource constraints required that most of the study focus on gathering, organizing, and interpreting existing information. This means, of course, that the results are not definitive, include many assumptions, and acknowledge large data gaps. We have confronted these data limitations by being explicit about them: the market analysis presents numbers in ranges; the risk assessment includes extensive sensitivity analysis; and for all areas, further information needs are highlighted. Consideration of assumptions and data limitations is an important responsibility of those using this report.

Based on the findings of this study, we feel that incineration on land or at sea is an environmentally sound treatment technology and that it offers advantages over current disposal options for liquid organic hazardous wastes under some circumstances. It also may help to meet the anticipated need for greater treatment and disposal capacity for this category of wastes in the future. We also agree with many citizens who are concerned about protecting our country's marine environment. However, given the current evidence indicating little adverse health or environmental impact from incineration, the safeguards provided by existing and proposed regulations, the existence of risks of some degree from other alternatives, and the need for sound methods of treatment and disposal for liquid organic hazardous wastes, we believe it is imperative for the nation to maintain the option of carefully controlled and monitored incineration activities on land and at sea.

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Barry Stoll, Marlene Suit.

Office of Research and Development:

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Market Study: Booze, Allen and Hamilton, Inc.

Comparative Risk Assessment: Industrial Economics, Inc.; Applied Science Associates, Inc.; Arthur D. Little, Inc.; and Engineering Computer Optecnomics, Inc.

Extensive review of all portions of this lengthy study was provided by a Steering Group composed of representatives from three EPA regional offices, all major EPA headquarters offices, and the U.S. Coast Guard. We express special appreciation to this Steering Group, and to additional reviewers listed below, for the many days spent reviewing draft reports and providing useful suggestions for improvement.

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CONCLUSIONS AND EXECUTIVE SUMMARY

The purpose of this study is to provide better information for EPA decision-making on hazardous waste disposal options by assessing the use of incineration for treatment of liquid organic hazardous wastes, including its advantages and disadvantages, and the issues associated with its use. The central focus is the detailed comparison of land-based and ocean-based incineration. A primary objective is to assist in decision-making on ocean incineration as the Agency develops regulations and research plans.

CONCLUSIONS

1. Incineration, whether at sea or on land, is a valuable and environmentally sound treatment option for destroying liquid hazardous wastes, particularly when compared to land disposal options now available.

The Agency's long-term goals are to reduce waste generation and encourage recycling. At the same time we must realistically deal with the wastes being generated now. Incineration destroys more than 99.99 percent of the hazardous constituents of the waste, and can destroy more than 99.9999 percent of wastes of special concern, such as polychlorinated biphenyls (PCBs). Risk assessments conducted by EPA indicate that properly designed and operated incinerators which meet the regulatory requirements for destruction efficiency pose minimal risks to human health and the environment. This is not an endorsement of any particular ocean or land-based hazardous waste incinerator facility. Each must be carefully evaluated as part of the permitting process.

2. There is no clear preference for ocean or land incineration in terms of risks to human health and the environment.

Because of its greater distance from populated areas, the human health risk from ocean incineration is significantly lower than the already low human health risks from land-based incineration. On the other hand, there is a remote probability that ocean incineration operations could result in a ship casualty and spill of hazardous waste. Such a spill could be relatively minor or cause substantial environmental damage, depending on the location, composition of the wastes, and extent of clean-up possible.

3. Although current commercial and on-site hazardous waste incineration capacities on land are adequate to handle existing demand (except for PCBs), future demand will significantly exceed this capacity as other disposal alternatives are increasingly restricted.

Market demand from waste generators for the use of incineration for hazardous wastes will increase substantially in the coming years due to implementation of new restrictions in the 1984 RCRA amendments, generators' increasing concerns with long-term liability, increased Superfund clean-up activities, and declining landfill capacity. Existing thermal treatment alternatives, such as destruction in cement kilns, may provide some additional capacity. However, emerging alternatives such as the plasma arc process are not expected to be commercially available on a large scale in the near future.

4. Although previous research has verified the destructive capabilities of incinerators, and risk studies have shown minimal impact on health and the environment, a program of continuing research is needed to improve our current knowledge of combustion processes and effects.

In particular, additional knowledge is needed about the full range of combustion by-products, including their quantities, toxicities, transport, and fate. For ocean incineration, information on potential effects could be significantly strengthened through improved stack and ambient monitoring, emissions characterization, and laboratory toxicity testing. The current research strategy of EPA's Office of Water, when carried to fruition, will provide much of this additional information.

5. In order to better address the concerns of citizens regarding incineration, EPA needs to improve its public communication efforts and provide more visible leadership in the area of hazardous waste management.

Public opposition to both land and ocean incineration may decline somewhat if EPA addresses more fully some citizen concerns regarding national regulatory strategy, local community impacts, equity of facility siting, and public decision-making processes. Clearly many of the public's concerns are also EPA's concerns, such as the potential health and environmental impacts from incineration. But the Agency needs to better communicate how health and environmental concerns and priorities are reflected in the Agency's regulations and standards. Better communication of EPA's overall regulatory policy, strategy, and activities for hazardous waste management is crucial in providing a context for decisions on proposed permits for individual incinerator facilities or vessels. Better public communication is also important for improving EPA's credibility with the public, which is a necessary foundation for the effective accomplishment of the Agency's mission.

EXECUTIVE SUMMARY

o Regulatory Approach

The current regulatory framework for incineration involves cradle-to-grave regulation of hazardous waste to be incinerated, provided jointly by EPA and the Department of Transportation (DOT). DOT regulates transportation, transfer and handling of hazardous waste. EPA regulates all phases of hazardous waste management, but focuses primarily on storage and disposal or treatment. Incineration is regulated by EPA under three statutes: the Resource, Conservation and Recovery Act (RCRA), the Marine Protection, Research, and Santuaries Act (MPRSA), and the Toxic Substances Control Act (TSCA).

EPA has now published a proposed regulation to provide more specific criteria to regulate ocean incineration under the MPRSA. In general, the proposed regulation adopts the most stringent requirements of RCRA, TSCA, and the London Dumping Convention, an international treaty. There are also some differences that reflect certain unique aspects of the marine environment or of the MPRSA and LDC.

° Assessment of Incineration Technology

Determination of the efficiency of incineration on land and at-sea is based on performance, not design. To date, testing has shown that incinerators are capable of destroying at least 99.99 percent of those compounds used as an indicator of overall performance. Critics have raised issues concerning the completeness of this approach, about testing procedures, and about the reliability of using only selected compounds to represent a complex emission that has not been fully characterized. EPA scientists acknowledge the need to continue researching combustion processes, but also believe that the current approach is the best now available and does provide for effective protection of the environment and human health.

- Assessment of the Incineration Market

The demand for both commercial and on-site incineration is expected to increase over existing capacity in the short to midterm due to restrictions in the 1984 RCRA amendments and other factors such as generators' increasing concerns with long-term liability from land disposal options. Projections of the specific amounts of additional capacity needed to meet demand cannot be made with accuracy due to the uncertainty of data and assumptions. Future demand for commercial incineration is expected to increase, but the size of the increase depends on a number of factors including: the specific policies and time frame for new RCRA disposal restrictions; future EPA actions which may create incentives or barriers for commercial incineration versus other waste management practices, especially treatment on-site; and the response of generators in developing additional on-site waste management capacity rather than relying on the commercial market.

- Assessment of Alternative Technologies

Emerging alternative technologies are seen to have minimal impact on the incineration market for managing liquid organic hazardous wastes. Their greatest impact will be on specialized, highly toxic waste streams that comprise only two to three percent of the market.

- Comparative Risk Assessment

Several general conclusions can be drawn about the relative risks to human health and the environment from land and ocean incineration operations by using generic models of incinerator facilities developed from combining various components of actual facilities. The overall human health and environmental risks of both the ocean and land-based systems are very low. The small amount of human health risk comes from incinerator stack emissions rather than emissions from transport and handling steps, with stack emissions accounting for more than 85 percent of all long-term, statistically expected, system releases from accidental spills and air emissions. In the case study developed, the resulting incremental risk of developing cancer for a hypothetical "most exposed individual" was on the order of two in a hundred thousand to one in a million for the various waste streams and locations. Human health risks from ocean incinerator stack emissions range from 30 to 40 times less than risks from land-based stack emissions, due to the greater distance from populated areas. Analysis of possible environmental effects of stack releases from ocean incineration indicated there would be no measureable effect on the marine ecosystem.

For ocean incineration, there are potential risks of spills during the ocean transportation phase of the operation. These risks, while unique to ocean incineration, have only a very remote probability of occurring. The total probability for casualties involving spills of any size is estimated to be one per 1200 operating years. For Mobile Bay and the coastal areas, the spill probabilities are one per 10,000 and 4,000 operating years respectively. EPA modelled the effects of hypothetical spills of ethylene dichloride (EDC) and of PCBs. While EDC spills would have relatively minor effects on the ecoystem, a spill of PCBs may have major effects.

- Public Concerns

There has been public concern about, and some very vocal opposition to, the siting and permitting of both land-based and ocean incineration operations. For ocean incineration, opposition has been regional in scope and has involved a wide range of groups and individuals. This is because citizens living along the Gulf of Mexico believe that any potential impacts on the marine and coastal environment will affect a very large, multi-state area. Many citizens who are concerned about ocean incineration are not completely against an ocean incineration program, but they do want significant safeguards and guarantees. For land-based incineration, opposition has been more localized in the immediate area of the facility, and has been strongest for off-site commercial facilities (especially those seeking to burn PCBs), rather than on-site facilities.

The immediate impact of citizen opposition has been to impede the siting of land incinerators or of port facilities for ocean incinerator ships, and to delay the issuance of permits for conducting burns on land and at sea. If opposition persists or grows, it may be difficult to develop additional commercial incineration capacity. More attention to public education, especially regarding how incineration relates to EPA's hazardous waste regulatory policy and strategy, may help to alleviate public concerns.

I. INTRODUCTION

A. Background

Each year, industry in the United States generates more than 264 million metric tons of hazardous waste which must be safely managed through treatment, storage or disposal. EPA's regulatory, permitting, and enforcement programs are gradually restricting the use of management practices deemed insufficient to protect the environment and human health. One effect of this is to reduce the available capacity for managing hazardous waste over the short-term.

Incineration is a technology which offers several advantages over some existing waste management practices and may help to meet the anticipated need for greater treatment and disposal capacity. However, public opposition to the permitting of new incineration operations has been strong. In response to the dilemma of perceived benefits versus public concerns, the Deputy Administrator requested this agency-wide assessment of incineration.

The regulation of incineration by EPA is complicated because it occurs in three different programs under three different statutes. The Office of Solid Waste developed standards for and permits land-based incinerators under the Resource Conservation and Recovery Act (RCRA). The Office of Toxic Substances developed standards for and approves the incineration of PCBs on land under the Toxic Substances Control Act (TSCA). The Office of Water has issued permits for ocean incineration under the Marine Protection, Research, and Sanctuaries Act (MPRSA), and is now proposing standards for ocean incineration under that Act.

B. Purpose

The purpose of this study is to provide better information for EPA decision-making on hazardous waste disposal options by assessing the use of incineration for treatment of liquid organic hazardous wastes, including its advantages and disadvantages, and the issues associated with its use. The central focus is the detailed comparison of land-based and ocean incineration. Liquid organic hazardous wastes are chosen as a basis for comparison because they represent the type of waste able to be treated by both land-based and ocean incineration.

A primary objective is to support decision making on ocean incineration as the Office of Water develops regulations and research plans, and begins to consider permit applications. The study will also assist in implementation of other aspects of EPA's hazardous waste management program.

C. The Analytic Tasks

Several different EPA offices contributed to the seven major analytical tasks which are the basis of this study. Each of the tasks addresses one central question.

(1) Incineration Technology - How do ocean and land based incineration technologies compare in terms of design, performance, and waste handling features? (Office of Management Systems and Evaluation)

(2) Waste Estimates - What volumes of liquid organic hazardous wastes are currently generated and stored in the United States, and what now happens to these wastes? (Office of Solid Waste)

(3) Market Analysis - What is the current market for incineration of liquid organic hazardous wastes, and what changes can be expected due to future regulatory actions? (Office of Policy Analysis)

(4) Assessment of Alternative Technologies - What new technologies are available, or will be available in the near future, to treat or destroy liquid organic hazardous waste, and how will this affect the market for incineration? (Office of Research and Development)

(5) Risk Assessment - What are the comparative risks to human health and the environment from land-based and ocean incineration of liquid organic hazardous wastes? (Office of Policy Analysis)

(6) Public Concerns - What are citizens' attitudes and concerns that affect the siting and permitting of incinerators? (Office of Management Systems and Evaluation)

(7) Regulatory Context - How do the three incineration regulatory programs compare, what other regulatory programs affect incineration, and who implements these programs? (Office of Managment Systems and Evaluation)

This paper integrates and summarizes the information contained in the seven study tasks, and presents conclusions based on that information. To aid in presentation, we have grouped together the findings from the Waste Estimates, Market Analysis, and Alternative Technologies tasks into one section on market-related issues.

More detailed information can be obtained from the much longer background reports that are summarized in this paper. They are: (1) Description of Incineration Technology, (2) Assessment of Emerging Alternative Technologies, (3) Assessment of the Commercial Hazardous Waste Incineration Market, (4) Comparison of Risks from Land-Based and Ocean-Based Incineration, and (5) Public Concerns Regarding Land-Based and Ocean-Based Incineration.

D. Relationship to Other EPA Work on Incineration

During the course of this study, three related EPA efforts focused on incineration of hazardous waste have been in progress. Two of them address the adequacy of existing scientific information and the need for further research. The third activity has been the work of drafting proposed regulations for ocean incineration.

At the request of EPA's Administrator, the Environmental Effects, Transport and Fate Committee of EPA's Science Advisory Board (SAB) conducted a scientific assessment of the incineration of liquid organic hazardous wastes at sea and on land. The Committee examined scientific data in five areas to determine if the Agency has considered and interpreted this data in a scientifically appropriate manner. The areas were waste transportation, combustion and incineration, stack and plume sampling, environmental dynamics and transport, and research needs. We have kept in close contact with the SAB committee during their work, and have had access to draft products. The SAB report, which will be published in the near future, includes specific recommendations for further research or reconsideration of existing data.

The Office of Water initiated the development of a comprehensive research strategy, in order to address the adequacy of current information on the environmental and human health effects of ocean incineration. The strategy identifies the types of research they believe necessary to determine the environmental effects of ocean incineration. When completed, the strategy will be used to guide future research by EPA and the ocean incineration industry.

Information from the work of the research strategy and the SAB report has contributed to this incineration study. Areas of concern identified by the SAB have helped to guide the work of our risk assessment, and SAB issues are reflected in our sections on technology, risk, and information needs. The Office of Water's draft research strategy is reflected in the section on information needs contained in the technology description.

The third important effort is the development of proposed regulations for ocean incineration by the Office of Water. We have worked closely with the regulation writers throughout this study, and draft products from these efforts have helped to guide and inform each other. Many elements of this study will be used by the Office of Water in making a generic analysis of the need for ocean incineration prior to making specific permit determinations.

II. OVERVIEW OF FINDINGS

This section presents a brief overview of the findings of this study, in terms of what we know and what we don't know about incineration at the present time. The discussion provides highlights about our regulatory approach, incineration technology, market considerations, health and environmental risks, and public opposition.

A. Regulatory Approach to Incineration

The current regulatory framework for incineration involves cradle-to-grave regulation of hazardous waste to be incinerated, provided jointly by EPA and the Department of Transportation (DOT). DOT regulates transportation, transfer and handling of hazardous waste. EPA regulates all phases of hazardous waste management, but focuses primarily on storage and disposal or treatment of hazardous waste. EPA also requires the companies to provide for emergency response in the event of unexpected releases.

Incineration is regulated by EPA under three statutes: RCRA, MPRSA, and TSCA. The regulatory program for land-based incinerators is still fairly new, since final regulations for the RCRA permitting program were not issued until 1981. The MPRSA permitting program for ocean incinerator ships began in 1974. Since 1974, however, EPA has issued permits for only four series of ocean burns: three in the Gulf of Mexico and one in the Pacific Ocean. These permits were issued under the authority of the MPRSA and using the regulations and guidelines of the London Dumping Convention (LDC). Making use of this experience in conducting operational and environmental monitoring, EPA has now drafted proposed regulations for ocean incineration which provide more specific criteria and standards for ocean incineration permits.

The proposed regulation for ocean incineration has many similarities to the RCRA regulations for land incineration. Both land and ocean regulatory programs use the same performance standard for incinerators, based on a destruction efficiency or destruction and removal efficiency of at least 99.99%. Both measure destruction efficiency using a small number of principal waste constituents as an index to represent all hazardous constituents contained in the waste. Both programs also require a trial burn to demonstrate that the performance standard will be met and to identify appropriate operating conditions to be specified in the operating permit. In general, the proposed ocean incineration regulation, recently released for public comment, adopts the most stringent requirements of existing regulations under LDC, RCRA, and TSCA.

While the control of hazardous waste incineration is based primarily on federal laws and regulations, the responsibility for implementing regulatory programs affecting incineration involves all three levels of government. In addition to broad federal responsibilities, state and local governments are involved in the areas of enforcement, facility siting, and emergency response to accidents.

B. Incineration Technology

Incineration is not a new technology and has been commonly used for treating liquid organic hazardous waste for many years in Europe and the U.S. The major benefits of incineration are that the process actually destroys most of the waste rather than just disposing of or storing it; it can be used for a variety of specific wastes and is reasonably competitive in cost compared to other disposal methods. In the U.S., there are currently 25-40 commercial land-based incinerator facilities and 200-210 onsite incinerator facilities. Ocean incineration was introduced in the United States as a new adaptation of the technology in 1974, with several burns being conducted in U.S. waters. Currently in the U.S, one company owns two incinerator ships (now operating in European waters), another has two ships under construction, and two companies have developed conceptual designs for ships.

The most common types of incinerators now in use are liquid injection and rotary kiln incinerators. The liquid injection incinerator is capable of incinerating a wide range of liquids, gases, and slurries; it is the most common type used on land, and also the type used in all ocean incinerator vessels. The rotary kiln with liquid capability is far less common, but is used by most major commercial land-based operators because of its versatility in handling solid, sludge, liquid, and gaseous wastes, either separately or simultaneously.

There are some important differences in the design of incinerators used on land and at sea. Land incineration uses liquid injection, rotary kiln, or other types of incinerators, but all types generally include air pollution control equipment in order to meet air emissions standards for hydrogen chloride (HCl) and particulates. Ocean incineration uses liquid injection incinerators without air pollution control systems, based on the fact that there are no nearby human populations at risk, and the expectation that HCl emissions will be rendered harmless by sea water.

EPA believes that incinerator efficiency is best determined by the ability to achieve acceptable performance levels, and not by incinerator design. The performance-based system is used largely because there are a wide variety of incinerator designs which are capable of adequately destroying wastes when properly operated and maintained.

Performance of hazardous waste incinerators is normally measured in terms of destruction efficiency (DE) or destruction and removal efficiency (DRE). Destruction efficiency refers to the percentage of hazardous constitutents destroyed in the combustion chamber, while destruction and removal efficiency accounts for both the destruction in the combustion chamber and removal of remaining original hazardous constituents by air pollution control equipment. The RCRA regulations require a DRE of 99.99%, while the proposed ocean incineration regulations require a DE of at least 99.99% for most principal organic hazardous constituents (POHCs). The DE required for incineration of polychlorinated biphenyls (PCBs), dioxins, and dibenzofurans is 99.9999%.

Because many of the wastes to be incinerated are complex mixtures of many different compounds, EPA uses a system which selects principal organic hazardous constituents (POHCs) to serve as indicators for the destruction of all constituents in the waste feed. POHCs selected are those considered most difficult to incinerate, with incinerability based on a calculation of "heat of combustion." Past test results show that properly designed and operated land and ocean incinerators are capable of meeting EPA's performance standard requiring destruction efficiency of 99.99% for POHCs.

There are a number of technical issues currently under discussion in the scientific community which relate to the adequacy of the Agency's current information or regulatory approach. These issues are briefly outlined below.

1. Products of Incomplete Combustion (PICs). In the process of combustion, whether burning hazardous wastes or fossil fuels, incinerators and other combustion devices may cause the formation and emission of potentially harmful substances that are not present in the initial feed. Concern about the creation of these substances, called products of incomplete combustion, became acute in the late 1970's with the discovery of chlorinated dioxins and furans in the emissions of many incinerators burning municipal refuse and hazardous wastes.

Because studies to date indicate that reported levels of PICs from well operated incinerators present very low risks, EPA has not regulated the emission of PICs. However, everyone agrees that more information on PICs is needed. For example, the Science Advisory Board report recommends a more comprehensive characterization of emissions to provide an improved estimate of risks for both land and ocean incineration. The risk assessment prepared for this study analyzes the risks from PICs, but the studies available to us did not provide the degree of characterization recommended by the SAB.

2. The Adequacy of the POHC System. Some persons have questioned the utility of the POHC system, particularly the heat of combustion index. They claim that it does not allow adequate determination to be made of the incinerability of complex mixtures of chemical compounds. EPA is continuing to assess the reliability of this system, but believes that the heat of combustion measure is still the best system currently available. Also, since the normal operating temperatures of incinerators are hundreds of degrees higher than temperatures needed to destroy compounds at the top of all incinerability hierarchies, the issue of selecting an ideal system for ranking POHCs is not crucial.

3. Maintaining Performance. Because in some previous tests EPA only measured performance for short periods during optimum operating conditions, the Science Advisory Board recommended that EPA examine more closely the frequency and effects of "upset conditions" which might result in increased emissions to the environment. This year EPA is conducting a series of research burns to provide information on emissions under abnormal or "off-design" conditions which might occur from waste composition anomalies or mechanical failures. In addition, since current permitting guidance recommends that trial burns conducted for permitting be extensive, the burn would normally include short-term sub-optimal conditions. Permit conditions therefore include temperature and other requirements to assure a DRE greater than 99.99% for continuous operating conditions rather than short-term optimal conditions. Long-term upset conditions require termination of hazardous waste fuel feed until the upset condition is corrected.

4. Monitoring. Questions have been raised regarding both stack emissions monitoring and ambient environmental monitoring. There have been criticisms that sampling practices have not been consistent and that analytical techniques have not been adequately verified for both land and ocean systems. In addition, monitoring on ocean vessels presents unique problems because the stack gases have very high exit temperatures due to the absence of pollution control equipment. These issues for stack emissions monitoring are being addressed in the research programs of the Office of Research and Development and the Office of Water. The Office of Water's research agenda also outlines a program for more thorough ambient monitoring for ocean incineration than has been conducted for past burns.

C. Market Considerations for Incineration

According to a 1981 EPA survey of hazardous waste generators, about 264 million metric tons (MMT) of solid and liquid waste were generated that year. Less than one percent of these wastes were liquid wastes that were incinerated. Of the total liquid wastes incinerated, only about ten percent, or .14 MMT, were burned at off-site commercial facilities, while ninety percent were incinerated by the generators.

Our estimates indicate that available on-site and commercial incineration capacity for liquid waste other than PCBs is not now fully utilized. Estimates for utilization of commercial liquid incineration capacity vary from 40 to 80 percent, with 55 percent the mid-range estimate. PCBs are an exception to this finding. Since only four off-site firms have received approval for incineration of PCBs, capacity for PCBs is currently fully utilized. Industry sources indicate a 2 to 3 month backlog over capacity and expect demand to further exceed supply because of accelerated voluntary phase-out. PCB capacity could be increased substantially if current permit applications from two large existing commercial facilities are approved, but this would decrease capacity for incineration of other liquids.

Although current land-based commercial and on-site hazardous waste incineration capacities are adequate to handle existing demand (except for PCBs), future demand will significantly exceed this capacity as other disposal alternatives are increasingly restricted. Demand for incineration is expected to increase substantially in the coming years due to implementation of the 1984 RCRA amendments, generators' increasing concerns with long-term liability, increased Superfund clean-up activities, and declining landfill capacity. While existing thermal alternatives such as destruction in cement kilns may provide some additional capacity, emerging alternatives such as the plasma arc process are not expected to be commercially available on a large scale in the near future.

We estimated the effect of regulatory restrictions on liquid waste incineration demand using four scenarios: landfill restrictions, deep well injection restrictions, disposal impoundment prohibitions, and waste-in-boilers restrictions. Because of uncertainties in estimating the effects of these restrictions, low, high, and mid-range estimates of increased demand were used. If all four scenarios are combined, a mid-range estimate of demand for commercial incineration would be 7 1/2 times current capacity, and the commercial capacity shortfall would be 1.65 MMT/year.

Minor increases in liquids capacity could occur if some existing incinerators alter waste feeds to burn fewer solids and more liquids. Thermal industrial processes involving cement kilns, lime kilns, and aggregate kilns have also been used for commercial destruction of hazardous waste, and the potential for more capacity exists. Capacity could also be increased through construction of more land-based incinerators, but incineration firms reported that public opposition and permitting requirements cause 3 to 5 year delays in bringing new incinerators on line. If three incinerator ships were issued permits to operate in the U.S. (e.g., the two Vulcanus incinerator ships plus the first Apollo ship), they would add .25 MMT/year to commercial capacity, nearly doubling the current commercial capacity.

EPA examined the capabilities of a wide variety of emerging alternative technologies in various stages of design and development which might prove suitable for treating liquid organic hazardous wastes. The processes reviewed were identified through responses to two national solicitations, from literature reviews, and contact with experts in the field. EPA concluded that emerging alternative technologies will have a minimal impact on the market for liquid hazardous wastes currently being incinerated. Their greatest impact will be on specialized, highly toxic waste streams that comprise only 2 to 3 percent of the market. These technologies would probably be unavailable for commercial use for many years.

Although the market analysis indicates that demand for commercial incineration could increase substantially, this projection cannot be used to predict accurately the amount of commercial capacity which will be required. Future demand is dependent on advances in waste reduction and recycling, the new RCRA disposal restrictions, and other future EPA actions which may create incentives or barriers for commercial incineration versus other waste management practices, especially treatment on-site.

D. Comparative Risk Assessment

As part of the incineration study, EPA developed a risk assessment case study which compares the human and environmental exposure and effects likely from releases of land-based versus ocean incinerators. The study integrates existing information and adds new analyses developed from existing methods and data. No new primary research was completed, so conclusions are limited by the availability and quality of information on emissions, transport, fate and effects.

1. Incineration Systems Considered. The study separated land and ocean-based incineration systems into three and four separate physical components, respectively. Both systems include land transportation, transfer and storage operations and incineration. The ocean incineration system also includes an ocean transportation step.

The ocean-based system considered has a configuration similar to that proposed by Chemical Waste Management, Inc. (CWM), to operate the Vulcanus II from Mobile, Alabama to the Gulf of Mexico burn zone. However, the study assumes that an integrated storage and transfer facility is located at the port. The land-based system is not modeled on any single incinerator, but combines characteristics of several existing commercial facilities. Since the systems reviewed are generic and not specific, the results of this effort are not sufficient to determine the risks associated with any specific land or ocean-based incineration proposal.

The study does not examine releases on land from major accidents involving fire or explosion at storage facilities. The probability of such events occurring is very low, and since both systems require similar storage facilities, the potential for events of this type would be the same for both systems. The study assumed that incineration would occur for two simplified waste streams with single hazardous constituents: one containing 35 percent polychlorinated biphenyls (PCBs) by weight, and a second containing 50 percent ethylene dichloride (EDC) by weight.

2. Quantities of Waste Released. The starting point for the analysis was to determine the statistically expected amount of pollutant released from accidental spills and air emissions. Considering all releases from each component of the incineration systems and for both waste streams, the transportation and handling components accounted for less than 15 percent of expected releases, while incineration stack releases accounted for more than 85 percent.

The analysis of land transportation considers two types of potential losses -- spills from vehicular accidents and spills from enroute container failures. The study estimates of spills are based on U.S. Department of Transportation (DOT) data pertaining to all tank trucks carrying hazardous materials. Use of this data with our case study assumptions regarding miles traveled indicates that accidents releasing any cargo are expected to occur on the average once every 4 to 5 years, and container failures once every 3 to 4 years. Hazardous waste services firms supplied information which indicates that the DOT average accident rates are higher than those actually experienced by the firms. This is perhaps due to special management practices and the use of stainless steel tanks more resistent to rupture than aluminum tanks. Our expected annual release estimates of 2.1 and 2.7 metric tons per year for the PCB and EDC wastes represent, on average, about 0.5 percent of annual transportation related releases of hazardous materials in EPA Region IV.

The analysis of transfer and storage considers three types of releases: spills when unloading wastes from tank trucks; spills from equipment at waste transfer and storage facilities; and fugitive emissions from transfer and storage. Spills from transfer and storage components are infrequent events, estimated to occur at a rate of about .04 to .05 per year for transfer of wastes from tank trucks, a rate of .03 to .04 per year for equipment and storage tanks, and a rate of .002 to .003 per year for the hose loading wastes to the ship in the ocean system. Spills of these types are likely to be contained at the facility. Fugitive emissions would also result in expected releases of 0.6 to 0.7 metric tons per year, resulting in total expected releases of 1.1 to 1.2 metric tons from transfer and storage. The total number of spills from transport and handling would represent, on average, less than 0.1 percent of the number of spills of hazardous materials likely from fixed facilities in EPA Region IV.

About 320 voyages of incineration ships in the North Sea have been made since 1972 and no casualties or spills have occurred. Estimates for spill rates used in this study are based on the worldwide historical record of tank ships of a similar size and class. The historical rates were adjusted to take into consideration the design of the Vulcanus, operating restrictions imposed by the Coast Guard, and the soft bottom conditions in the Gulf of Mexico.

Spills from the vessel would be very infrequent events. We estimate that the frequency of all spills for the Vulcanus is about one per 1,200 operating years. However, the frequency of spills estimated for any particular location is less. For example, the overall spill rate for the pier and harbor area is about one per 3,000 operating years; for Mobile Bay about one per 10,000 operating years; for the coastal area about one per 4,000 operating years; and for the burn zone about one per 6,000 operating years. These estimated spill rates are for all sizes of spills. Spills involving two or three or more tanks would be extremely unlikely events. For example, the estimated rate for spills in Mobile Bay involving two tanks is about one per 67,000 operating years, and about one per 200,000 operating years for spills in the Bay involving three or more tanks.

The tonnage carried by the Vulcanus is small in comparison to commercial shipments of petroleum and hazardous substances in the Gulf area. For example, the cargo carried by the Vulcanus would be only about 0.01 percent of petroleum and hazardous substances transported in the Gulf area. Since the Vulcanus has a lower spill rate than other vessels, the potential for releases from the Vulcanus is only about 0.002 percent of that from ongoing shipments of petroleum and hazardous substances in the Gulf area.

Incineration itself is the major release point in both systems. The study estimates total releases of organics and metals for the PCB wastes is 22.5 metric tons per year for both systems if one includes both stack releases and scrubber effluent. Under the assumptions of this case study, metals account for the largest portion of the releases.

3. Effects from Incinerator Releases. The study estimated and compared possible human health and environmental effects due to incinerator releases and fugitive releases from transfer and storage equipment.

Our analysis of human health risks estimates the incremental risk of developing cancer for a hypothetical "most exposed individual" (MEI) who resides at the location of the highest overall risk due to air concentrations resulting from incinerator stack and transfer/storage fugitive releases. For the land-based system, the location of the MEI is based on Census data; whereas for the ocean-based system the MEI is assumed to reside at that point on the coast where modelled concentrations are highest averaged over a year. These risk estimates assume 70 years of continuous exposure.

Table 1

SUMMARY OF INCREMENTAL CANCER RISK TO MOST EXPOSED INDIVIDUAL FROM INCINERATOR RELEASES

	PCB Waste	EDC Waste
Ocean-based System*		
Stack (coastline)	6.37×10^{-7}	1.06×10^{-6}
Fugitives (port)	2.02×10^{-8}	4.97×10^{-10}
Land-based System (average of two sites)		
Stack	2.74×10^{-5}	3.14×10^{-5}
Fugitives	7.05×10^{-7}	1.69×10^{-8}
Total	2.81×10^{-5}	3.14×10^{-5}

* The ocean system is not totalled because the releases are at different locations.

Table 1 presents the incremental risk of developing cancer for the most exposed individual due to releases from land- and ocean-based fugitive (transfer/storage) and stack releases. As shown, the incremental risks from land-based incineration releases are about three chances in one-hundred thousand for the locations and wastes considered. Virtually all of the incremental risk to MEI is due to stack releases, with fugitive releases resulting in increased risks of less than one in one million. Incremental risks to the most exposed individual at the coastline for the ocean-based system range from one in one million to 6 in ten million. As shown, the risks from fugitives to the MEI near the port facility are less than two per one hundred million.

The data and methods used to generate these incremental risk estimates are highly uncertain and tend to overestimate expected human health effects. Thus, the absolute risks levels indicated by these figures must be interpreted with caution. However, a comparison of the relative risks indicates that for the PCB waste, land-based emissions create about 40 times more incremental risk to the MEI than do ocean-based emissions. For the EDC waste, the ratio of land to ocean risk is about 30.

An evaluation of the possible environmental effects of stack releases was conducted for the ocean-based system. These analyses indicated there would be no measurable effect on the marine ecosystem. In fact, background atmospheric ~~flux~~ of PCBs into Gulf waters is two to three orders of magnitude greater than deposition from incineration of PCBs.

4. Effects from Ocean Transportation Releases. Although the probability of a spill is extremely low, the study characterized possible human health and environmental effects from spills at three sites: Mobile Harbor, over the continental shelf on the path to the burn zone, and in the burn zone itself.

The study examined possible human health effects due to volatilization following the extremely unlikely event of the loss of the entire vessel cargo. If the loss were to occur in the harbor within one kilometer of the city of Mobile, short term dosages exceeding health Threshold Limit Values would occur for populations directly downwind. Spills in other locations would not be expected to cause human health problems.

EDC spills would have relatively minor effects on the marine ecosystem. These small impacts are the result of this compound's rapid diffusion to low concentration levels and its relatively low toxicity to marine species. In addition, bioconcentration of EDC is not a significant phenomenon.

In contrast, substantial spills of PCBs would have major effects on the marine ecosystem. These effects range from being quite severe in the Bay (substantial reduction in benthic species and large bioconcentration effects on fish and shrimp) to less severe in the burn zone area. Since PCBs are a persistent compound such effects are expected to last a long time. Bioconcentration effects in commerical and recreational species would be of most concern in the Bay and contaminated shelf areas.

E. Public Concerns Regarding Incineration

There has been public concern about, and some very vocal opposition to, the siting of both land-based and ocean incinerators. At the time of our survey in 1984, public hearings had been held for approximately two dozen land-based incinerator permits; fourteen involved some degree of opposition. These fourteen land-based facilities included three on-site and eleven off-site facilities, and were located (or proposed) in many different parts of the country. For ocean incineration, one company has applied for operating permits to burn in the Gulf of Mexico, and a second company has applied for a permit to burn in the Atlantic Ocean. Both companies have experienced public opposition to the siting of port facilities, and there has also been opposition to the burn site in the Gulf.

In general, ocean incineration has caused a greater degree of public opposition than most land-based incinerators. This is primarily because the perceived impact of land-based incineration is very localized, whereas ocean incineration is thought by some citizens to potentially affect an entire region: the port community, all the communities along the coastline near the burn site, and the marine environment. While the source of opposition to both ocean and land incinerators has been primarily from local communities, ocean incineration is unique in also being actively opposed by some multi-state coalitions of civic, business, and environmental groups, and by some national environmental groups.

For land-based incineration, on-site facilities that directly serve a single waste generator have greater public acceptance than off-site, commercial incinerators that serve multiple generators in a large market area. Interviews and public hearing transcripts indicate that many people feel that off-site facilities do not provide sufficient economic benefits to the local community to offset the risks associated with the importation of wastes from other areas. On-site facilities are more clearly perceived as being linked to businesses that are important to the local economy, and are generally not perceived as being importers of hazardous waste. Opposition to land-based facilities has tended to focus primarily on new, off-site commercial facilities, which share many similarities to ocean incineration; and on new applications to burn PCBs, which critics view as particularly hazardous.

For land-based incineration, the two areas of concern cited most often by critics are potential health risks from air emissions and potential risks and impacts of spills from routine transport, handling, and storage. For ocean incineration, the concerns mentioned most often are potential risks of spills from routine transport activities and from catastrophic incidents, and the feeling that EPA has, in the past, done a poor job of managing the ocean incineration regulatory program. While many people concerned about ocean incineration are not completely against an ocean incineration program, they do want significant safeguards built into the regulations.

The immediate impact of citizen opposition has been to impede the siting of land incinerators and of port facilities for ocean incinerator ships and to delay the issuance of permits for conducting burns on land and at sea. The long-term effect of continued opposition may make it difficult to develop further incineration capacity. Solutions offered by the public to problems with siting land incinerators have usually been to "put it someplace else," although many people have suggested that it might help for EPA or the states to develop explicit siting criteria. Solutions offered for concerns about ocean incineration focused either on using strict regulations and explicit siting criteria or on banning incineration at sea and relying on land disposal methods. In either case, critics want EPA to promote other long-term solutions to hazardous waste management, such as waste recycling, reduction, and detoxification.

Public opposition to incineration on both ocean and land may be reduced somewhat if regulatory agencies more fully address public concerns regarding basic regulatory policy and strategy, enforcement resources, local community impacts, equity of facility siting, and public decision-making processes. In large part this is a matter of taking the time and effort to better inform the public about the "big picture" (i.e., the Agency's overall regulatory policy, strategy, and activities for hazardous waste management), in order to provide a context for discussions of permits or siting decisions for individual incinerator facilities. The fact that EPA has a national hazardous waste management strategy to encourage long-term solutions is not very helpful if the public does not know about it. Improved communication and more visible leadership from EPA would go a long way toward resolving many of the issues and public concerns discussed here.

III. REGULATORY APPROACH AND CONTEXT FOR INCINERATION

Under federal statutes, all incineration facilities handling hazardous wastes must obtain permits through which federal requirements are applied to individual incinerators. Three statutes govern the regulation of incineration, and these statutes are implemented by two separate permitting programs.

EPA regulates land-based incineration in the Office of Solid Waste under the Resource Conservation and Recovery Act (RCRA). Incineration of PCBs is regulated by the Office of Toxic Substances under the Toxic Substances Control Act (TSCA). Ocean incineration is regulated by the Office of Marine and Estuarine Programs under the Marine Protection, Research, and Sanctuaries Act (MPRSA) and under the London Dumping Convention, an international treaty.

A. HISTORICAL CONTEXT FOR REGULATION OF INCINERATION

1. Land-Based Incineration

Regulation of hazardous waste is a relatively recent development in the United States. Early environmental laws were aimed at controlling the more obvious sources of pollution of air and surface water. However in 1976, Congress passed the Resource Conservation and Recovery Act to prevent damage to human health and the environment from the mismanagement of waste, a less obvious source of pollution of air, surface water and ground water. RCRA regulates all waste, including liquid, sludge and solid, hazardous and non-hazardous, and all methods of management, including disposal, storage, treatment, and recycling. RCRA thus covers the incineration of liquid organic hazardous wastes, the subject of this report.

Incineration is a waste reduction and treatment method that has been used by industry for a number of years. But the regulatory program for land-based incinerators is still fairly new, since final RCRA regulations establishing standards for incineration were not issued until 1981. Under these regulations, all new and existing land-based incinerators must receive an operating permit, issued either by an EPA Regional office or by an EPA-authorized state agency.

While the regulatory program was getting underway, Congress allowed those incinerator facilities already in existence on November 19, 1980, to operate under "interim status" until their permit applications are requested by EPA (or the state) and a decision is made to approve or deny a a permit, based on full evaluation of the facility's performance. About 350 existing facilities applied for interim status. These facilities included those that consist exclusively of incinerators and those that include incinerators among several waste management methods. As EPA has requested permit applications, some companies have chosen to close down their incinerator facilities rather than spend the resources necessary for obtaining a permit and modifying their operations and equipment to comply with federal standards. As of February 1985, the Agency has received 200 permit applications from existing incinerator facilities, and has issued 23 final permits.

For new incinerator facilities, the operator must receive a RCRA permit before starting construction of the facility. At this time, only four permits have been issued for new incinerator facilities.

2. Incineration of PCBs

In the same year that RCRA was passed, Congress also passed the Toxic Substances Control Act, partly in response to concern about potential health hazards from PCB contamination. TSCA imposed a ban on the manufacture of PCBs, and in 1978 and 1979 EPA issued regulations for proper PCB marking and disposal, which included high-temperature incineration as an approved disposal/treatment method.

If an incinerator operator wants to burn PCBs, he must receive special approval from EPA headquarters. PCB approvals are usually incorporated into RCRA permits issued by EPA Regional Offices or authorized state agencies, or incorporated into MPRSA permits issued by EPA headquarters. However, existing incinerator facilities with interim status under RCRA may obtain an approval to burn PCBs before receiving a final RCRA permit. So far, EPA has approved PCB incineration for 15 land-based incinerator facilities and for one research permit for an incinerator ship.

3. Ocean Incineration

Incineration at sea has been used by some European countries since 1972, both because of a shortage of land for disposal and because ocean incineration is considered to be environmentally preferrable to most land disposal options for hazardous waste. Use of ocean incineration was first proposed in the United States in 1974, when Shell Chemical Company, prohibited from continuing to dump liquid organochlorine wastes in the Gulf of Mexico, hired a Dutch company to incinerate those wastes in the Gulf.

In 1972, Congress passed the Marine Protection, Research, and Santuaries Act, which regulates the transportation of material from the U.S. for the purpose of dumping into ocean waters, and prohibits ocean dumping of wastes without a federal permit. The purpose of this law was to strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities. Ocean dumping regulations were issued in 1973, and Shell was subsequently prohibited from dumping its untreated organochlorine wastes in the ocean after November 1973. Shell then began storing its wastes in aboveground tanks at its plant in Deer Park, Texas, and in 1974 the company hired Ocean Combustion Services, operating out of the Netherlands, to incinerate their wastes using the Vulcanus incinerator ship.

Initially EPA believed it did not have regulatory authority over ocean incineration, based on lack of evidence in the Ocean Dumping Law (i.e., MPRSA) and its legislative history that Congress intended to deal with airborne pollutants in the ocean dumping act. However after careful consideration, including discussions with Congressman Dingell, a chief author of the MPRSA, and with the National Wildlife Federation, an organization that took an early interest in this issue, the Agency decided that it did have jurisdiction over incinerator ships as "indirect" ocean dumpers. This interpretation was based on the Agency's concern that the failure to regulate recently developed waste disposal techniques involving ocean incineration would frustrate the purposes of the MPRSA and the London Dumping Convention. Thus in 1974 ocean incineration became prohibited without a federal permit. This was two years prior to regulation of land-based incinerators under RCRA.

EPA issued the Ocean Dumping Regulations in 1973, thereby establishing criteria for evaluating permit applications. But these regulations do not provide specific technical criteria for incineration activities. EPA has therefore issued permits for ocean incineration using administrative and technical criteria from both the Ocean Dumping Regulations and the regulations and technical guidelines of the London Dumping Convention.

The London Dumping Convention (officially referred to as the Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter) was entered into in 1972 to address the growing concern of several nations that marine pollution had developed into a serious environmental problem. The United States was a leader in initiating the Convention, basing its position on the newly signed MPRSA. The London Dumping Convention entered into force in 1975 when the minimum required number of 15 nations (including the U.S.) ratified it as an international treaty. The LDC requires each ratifying nation (52 countries at the present time) to regulate by permit the dumping or incineration of wastes loaded from its ports.

After the LDC went into effect in 1975, the parties to the LDC adopted regulations and technical guidelines for incineration at sea. The regulations establish technical standards, including combustion and destruction efficiency, operating conditions, and monitoring parameters, and also administrative standards such as recordkeeping requirements. The United States must apply the LDC's regulations and take "full account of" the technical guidelines in developing permits.

Regulatory activities began in October 1974 with a joint proposal by EPA, the National Wildlife Federation, and Shell to evaluate incineration at sea as a viable alternative to direct ocean dumping, land disposal or land incineration for highly toxic substances. During 1974 and 1975, Shell conducted two research burns and two operational burns in the Gulf of Mexico. Based on the data and experience gained from these initial burns, this first U.S. use of ocean incineration for the disposal of organochlorine wastes was rated a success and an environmentally acceptable practice when closely monitored and regulated.

Between 1974 and 1982, the EPA issued permits for four series of burns conducted by the Vulcanus I ship: three in the Gulf of Mexico and one in the Pacific Ocean. Making use of this additional experience in conducting operational and environmental monitoring, EPA has now developed proposed ocean incineration regulations which provide specific criteria and standards for ocean incineration permits, and criteria for designating and managing ocean incineration sites.

B. FEDERAL REGULATION OF INCINERATION SUPPORT ACTIVITIES

Incineration is the last phase in a "cradle-to-grave" set of linked activities. The actual burning of hazardous wastes requires support facilities for storage, transportation, and transfer of wastes. Current authorities for regulating the support aspects of ocean and land-based incineration are summarized in Table 1, and are described in the following pages.

1. Storage Facilities

The RCRA regulations apply to any waste storage facilities on land, including those used to support land-based and ocean incineration. This includes separate storage facilities such as Chemical Waste Management's facility at

Table 1: Federal Regulatory Framework for Incineration

Major Statutes/Regulations	Responsible Authorites	Relevant Areas Covered by Statutes/Regulations:	
		Ocean	Land-Based
Resource Conservation and Recovery Act (RCRA)	- EPA Headquarters and Regions, and authorized states	- Content and storage of wastes. - Waste transport on land.	- Content and storage of wastes. - Waste transport on land. - Incineration on land.
Toxic Substances Control Act (TSCA)	- EPA Headquarters and Regions	- Incineration of PCBs.	- Incineration of PCBs.
Marine Protection, Research, and Sanctuaries Act (MPRSA) (Ocean Dumping Regulations)	- EPA Headquarters - U.S. Coast Guard	- Ocean incineration.	N/A
London Dumping Convention Regulations and Interim Guidelines (LDC)	- Party nations to LDC	- Ocean incineration.	N/A
Coastal Zone Management Act (CZMA)	- States with Federally-approved CZM programs (by NOAA)	- Activities affecting land or water uses in the coastal zone.	- Activities affecting land or water uses in the coastal zone.
Hazardous Materials Transportation Act and associated regulations	- U.S. DOT • Materials Transportation Bureau • Federal Highway Admin. • Federal Railroad Admin • Coast Guard - State Highway Depts.	- Hazardous waste transport by truck, rail, and water.	- Hazardous waste transport by truck and rail.
46 USC Ch. 37 (Former Port and Tanker Safety Act)	- U.S. Coast Guard	- Design, construction, certification, and operation of incinerator vessel.	N/A
Port and Waterways Safety Act and associated regulations	- U.S. Coast Guard	- Incinerator vessel movement through port area. - Storage and transfer of wastes at waterfront facilities	N/A
Clean Water Act	- EPA - U.S. Coast Guard	- Clean-up of oil and designated hazardous substance waste spills in U.S. territorial waters.	- Clean-up of oil and designated hazardous substance waste spills in U.S. inland waters.
Act to Prevent Pollution from Ships	- U.S. Coast Guard	- Limits on operational discharges from ships	N/A
Comprehensive Environmental Response, Compensation, and Liability Act (i.e., Superfund)	- EPA Headquarters and Regions - U.S. Coast Guard	- National Contingency Plan - Clean-up of spills	- National Contingency Plan - Clean-up of spills

Emelle, Alabama, and any waterfront transfer facility that involves storage for more than ten days. If a waste generator stores wastes on-site for more than 90 days, he must apply for a RCRA storage permit. If a transporter stores wastes at a transfer facility for more than ten days, he must apply for a storage permit. If a transporter stores wastes for ten days or less, the facility is considered a transfer facility, not a storage facility. (Local building codes also regulate certain aspects of storage facilities, and may require additional safety features for storage of hazardous wastes.)

2. Transportation of Hazardous Wastes

Transportation of hazardous wastes is regulated by EPA under RCRA, and by the U.S. Department of Transportation primarily under three laws: the Ports and Waterways Safety Act, 46 USC Ch. 37 (formerly the Port and Tanker Safety Act), and the Hazardous Materials Transportation Act. To integrate the administration and enforcement of these various Acts, DOT and EPA executed a Memorandum of Understanding in 1980 that delineates areas of responsibility and coordination in the enforcement of standards applicable to shippers and transporters of hazardous waste.

RCRA regulations cover both inter and intrastate land transportation, and concern recordkeeping, reporting, labeling, containers, tracking wastes from generator to ultimate disposal site through the manifest system, and transportation of waste only to approved (i.e., permitted) facilities. HMTA regulations apply to all commercial transportation of packaged products and bulk shipments, whether interstate or intrastate, and require proper classification of materials, shipping papers, marking on packages, and safety precautions for vehicles. HMTA regulations are enforced by agencies in the Department of Transportation: the Materials Transportation Bureau regulates compliance with packaging standards; the Federal Highway Administration and Federal Railroad Administration regulate land transportation; and the U.S. Coast Guard regulates water-borne transportation.

Although many EPA and DOT requirements are similar, there are some areas over which only EPA or DOT has jurisdiction. One such area is the EPA requirement that transporters clean up any accidental discharges of hazardous waste. Another is the DOT requirement for the installation of certain safety features on all motor vehicles.

Either agency, or both, may bring enforcement action against transporters of hazardous waste. The two agencies routinely coordinate investigations and enforcement actions in order to avoid duplication. In practice, the EPA usually monitors activities at generator and waste management facilities, while DOT monitors all shipping in between, whether by highway, railroad, air or water.

The Coast Guard has a particularly important role in the control of hazardous waste transportation by water, which can be a supporting link for incineration either on land or at sea. This agency has regulatory responsibilities for many different aspects of hazardous waste transportation under a wide variety of statutes, as indicated in Table 2.

The Coast Guard is now in the process of collecting in one place in the Code of Federal Regulations existing regulations for the design and construction of incinerator ships. A proposed rulemaking to accomplish this will be issued in 1985.

3. Transfer Facilities

Transfer facilities or activities that are incidental to transportation activities are regulated under the Hazardous Materials Transportation Act and the Ports and Waterways Safety Act. Thus, land transfer facilities and activities are subject to all DOT requirements for proper packaging, containers, and labelling of hazardous wastes. Transfer facilities for loading ships must comply with Coast Guard requirements for all waterfront facilities, plus specific requirements for ships loading oil products or waste.

Waterfront or land-based transfer facilities are not subject to RCRA requirements unless the wastes are stored at the facility for more than ten days, in which case the transporter must apply for a storage permit and meet all storage requirements under RCRA.

4. Activities in the Coastal Zone

The Coastal Zone Management Act requires that anyone applying for a federal permit for an activity affecting land or water use in the coastal zone must certify that the proposed activity complies with federally-approved state coastal zone management programs. If an affected state disagrees, the applicant may appeal that judgment to the Secretary of Commerce. EPA cannot issue an incinerator permit until a final determination is made regarding compliance with state coastal zone management programs.

C. COMPARISON OF REGULATORY PROGRAMS FOR INCINERATION

RCRA regulations specify both performance standards and administrative standards for land-based incinerators that

Table 2: U.S. Coast Guard Responsibilities

Activity	Statutory Authority
Safety and storage of hazardous materials at waterfront facilities.	° Ports and Waterways Safety Act
Procedures and pollution prevention requirements for the transfer of hazardous materials between facilities and vessels.	° Ports and Waterways Safety Act ° Clean Water Act
Design, construction, and operation of vessels carrying hazardous materials.	° 46 USC Chapter 37 ° 46 App. USC 883 ° Marine Protection, Research, & Santuaries Act
Inspection and certification of vessels carrying hazardous materials.	° 46 USC Chapter 37
Supervision of hazardous materials transfer to vessels.	° Hazardous Materials Transportation Act ° Ports and Waterways Safety Act ° Marine Protection, Research, & Santuaries Act
Vessel movement control through port area.	° Ports and Waterways Safety Act
Aids to navigation.	° 14 USC Chapter 5
Limitations on operational discharges from ships.	° Act to Prevent Pollution from Ships ° Clean Water Act
Ocean dumping surveillance of vessels for enforcement of regulatory and permit requirements.	° Marine Protection, Research, & Santuaries Act
Responding to spills of oil and hazardous materials in the coastal areas of the United States.	° Clean Water Act ° Comprehensive Environmental Response, Compensation, and Liability Act (i.e., Superfund)

must be met before obtaining a permit. Incinerator units are subject to performance standards for: (1) the destruction and removal efficiency (DRE) of principal organic hazardous constituents (POHCs); (2) the emissions of hydrogen chloride; and (3) the emissions of particulate matter. A trial burn or alternative source of data is required in order to demonstrate that the incinerator can meet performance standards and to determine day-to-day operating parameters. For enforcement purposes, compliance with the operating parameters specified in the permit is regarded as compliance with the performance standards.

RCRA regulations also establish administrative standards for hazardous waste management facilities that apply to incinerator facilities in the following areas:

- waste analysis plan
- inspection of equipment
- monitoring of operating conditions
- facility security system
- personnel training program
- special controls on ignitable, reactive, & incompatible wastes
- location constraints based on risk of earthquakes & floods
- contingency plan to respond to fire, explosion, or accidental release of wastes
- manifest system, recordkeeping, and reporting
- facility closure plan and financial arrangements
- liability insurance for accidental occurrences

The PCB technical requirements for incinerators include general performance standards, operating conditions, and monitoring and recordkeeping requirements. The TSCA regulations distinguish between liquid and nonliquid forms of PCBs. For nonliquid PCBs, a high performance standard which translates into a 99.9999 percent destruction efficiency (DE) is established. For liquid PCBs, a performance standard of 99.9 percent is specified for combustion efficiency (not destruction efficiency), coupled with certain required operating conditions. However, in practice, the Agency has required a demonstration of 99.9999 percent DE for liquid as well as nonliquid PCBs.

The proposed regulation for ocean incineration has many similarities to RCRA regulations. Both the ocean and land-based regulatory programs evaluate incinerators primarily in terms of their capability to destroy a high percentage of the incoming waste. Both use performance standards rather than equipment design standards. Both have chosen the same standard of 99.99 percent (99.9999 percent for PCBs, dioxins and dibenzofurans), for destruction efficiency or destruction and removal efficiency, and measure a small number of principal organic hazardous constituents to represent all hazardous constitutents in the waste stream. Both programs require a trial burn to demonstrate that the performance standard will be met, and to identify appropriate operating conditions to be specified in the permit.

In general, the proposed ocean incineration regulation that was recently released for public comment adopts the most stringent requirements of existing regulations under the LDC, RCRA, and TSCA. In spite of many similarities, however, the ocean incineration program differs from the land-based program in several respects. The major differences are summarized in Table 3. One important difference, discussed below, regards the demonstration of "need" for ocean incineration.

1. "Need" for Ocean Incineration: Hazardous Waste Management vs. Marine Resource Protection

A statutory requirement unique to MPRSA involves determining a need for ocean incineration and ocean dumping in evaluating permit applications. Not only must the permit applicant demonstrate that all standards and environmental impact criteria have been met, but the Agency must consider the need for ocean incineration. This consideration of need is also part of the London Dumping Convention requirements that alternative land-based methods be examined prior to issuing ocean dumping permits.

As explained in the preamble to the proposed Ocean Incineration Regulation, in determining need, the environmental and human health risks of ocean incineration will be compared to those associated with practicable land-based alternatives, taking into consideration technical feasibility and economics. Need will be presumptively demonstrated if ocean incineration poses less or no greater risks than practicable land-based alternatives.

The preamble also describes EPA's approach to making the determination of need. The Agency will draw on this study and other sources to prepare a generic needs analysis, which will be made available to the public for review and comment. The analysis will be revised every five years to take into account new technologies. In determining the need for a particular permit, EPA will compare the risks of an applicant's operation with those identified in the Agency's generic needs analysis. Only where information is submitted or is available to the Agency which indicates that an applicant's operations are unique from those considered in the generic analysis or which demonstrate that the information on which the Agency based its assessment has significantly changed will the issue of need be reconsidered.

Table 3: Major Regulatory Differences

Areas of Major Differences	Ocean-based (proposed)	Land-based
• Technical Requirements		
- HCl/Particulate Emissions Limits	- Environmental performance standards (marine water quality).	- Air emissions performance standard (stack gas).
- Monitoring for PICs at the stack	- Emissions will be analyzed for PICs during research burns and at the discretion of EPA during trial burns.	- Not required during trial burn. However, monitoring for PICs is done during research burns.
- Shipriders	- EPA shipriders must be aboard vessel for transport and incineration phases.	- N/A
• Permitting Procedures		
- Public Comment	- Required public comment period (45 days) on data from trial burn.	- No formal procedures to consider public comment on trial burn data.
- Permit Duration	- Operating permits valid for up to 10 years, reviewed every 5 years.	- Operating permit valid for up to 10 years.
• Liability Issues		
- Financial Responsibility for sudden accidental occurrence	- Applicants required to have insurance coverage [range proposed in rule between $50 and $500 million]. Applicants could propose a lower level based on specific risk of the applicant's operation, EPA could also increase required level of insurance based on risk.	- Applicants required to demonstrate financial responsibility, guaranteed by assets or insurance, of at least $1 million per occurrence, or at least $2 million annual aggregate.
• Needs Determination	- The need for ocean incineration must be demonstrated when evaluating an operating permit application. EPA will develop a generic needs assessment to use in evaluating an applicant's operation and specific needs assessment.	- N/A

Whether the needs criterion implies that the ocean should be treated as a specially protected resource continues to be a source of disagreement. Those who favor the special protection approach argue that the oceans are a unique resource where cleanup is difficult if not impossible, and that our scientific understanding of the fate and effects of pollutants is very limited. Others believe that because of the remoteness of incineration sites from populated areas, the dispersal capacity of the atmosphere, and the vast dilution, dispersal, and assimilation capacity of the open seas, the oceans offer a significant waste management option which involves little or no health or environmental risk.

D. FEDERAL, STATE AND LOCAL RESPONSIBILITIES FOR IMPLEMENTING REGULATORY PROGRAMS AFFECTING INCINERATION

While the authority to control incineration is based on federal laws and regulations, the implementation of these and other regulatory programs that affect incineration involves all three levels of government. Table 4 outlines the parties responsible for implementing various regulatory activities that relate to each of the phases of cradle-to-grave waste management ending with incineration. The following discussion highlights implementation areas that have been of particular interest or concern to some citizens.

1. Siting

Siting of waste management facilities has historically been a local decision, although two states, New Jersey and California, have now developed siting criteria and exercise site approval authority before issuing operating permits. Local siting authority is based on zoning ordinances. Since difficulty in siting incinerators and other hazardous waste facilities is a continuing problem, and may to some extent hamper implementation of a national hazardous waste management program, there may be a growing need for EPA to become involved in the siting issue. Some members of the public have suggested that EPA ought to develop national siting criteria for land incinerators and for waterfront transfer facilities. Currently EPA's only involvement in siting is the designation and management of ocean burn sites.

2. Enforcement

As discussed earlier, EPA and DOT together have regulatory and enforcement authorities covering cradle-to-grave hazardous waste management activities. EPA's enforcement authority may, for the most part, be delegated to EPA approved state agencies. Either EPA or DOT, or both, may bring enforcement action against land transporters of hazardous waste. Enforce-

Table 4: Federal, State and Local Responsibilities for Implementing Regulatory Programs Affecting Incineration

Regulatory Activities	Phases of Hazardous Waste Managment Activities for Incineration Waste Transportation	Waste Transfer and Handling	Waste Storage Facilities	Incineration Facilities
Issue Regulations and Standards	Land: EPA, DOT/MTB	Land: DOT/MTB	Land: EPA, local government	On land: EPA, authorized states, local government
	Water: Coast Guard	Waterfront facilities: Coast Guard	Waterfront facilities: EPA, Coast Guard, local government	On ships: EPA, Coast Guard
Issue Operational Permits, Certificates, or other Prior Approvals	Land: none	Land: none	Land: EPA regions authorized states local government	Land: EPA regions, authorized states, local government
	Water: Coast Guard	Waterfront facilities: Coast Guard	Water: Army Corps of Engineers, Coast Guard	Ships: EPA Headquarters
			Coastal zone: States with CZM program	Coast zone: States with CZM program
Enforce Regulations, Standards, and Permits	Land: FHWA, FRA, MTB, states	Land: FHWA, FRA, MTB, states	Land: EPA regions, authorized states, local government	Land: EPA regions, authorized states
	Water: Coast Guard	Waterfront facilities: Coast Guard	Water: Army Corps of Engineers, Coast Guard	Ships: EPA Headquarters, Coast Guard
Approve Siting of Facility or Transport Route	Land: Local government, and some states	Land: Local government and some states	Land: Local government, some states	Land: Local government and some states
	Water: None	Water: None	Water: None	Water (burn sites): EPA
Emergency Response Activities (only if company fails to provide for adequate clean-up)	Land: Local government, states, EPA	Land: Local government, states, EPA	Land: Local government, states, EPA	Land: Local government, states, EPA
	Water: Local government, Coast Guard, EPA	Water: Local government, Coast Guard, EPA	Water: Local government, Coast Guard, EPA	Water: Local government, Coast Guard, EPA

ment of regulations for truck traffic is usually done by state police, while regulations for railroad transport are enforced by the Federal Railroad Administration. For waterborne transportation, the Coast Guard is solely responsible. Regulations for waste storage, waste content, and incineration are enforced by EPA or authorized state agencies.

3. Emergency Response

The party responsible for a spill is required to be financially responsible for its cleanup. Both EPA and the Coast Guard, as federal On-Scene Coordinators (OSC), encourage the responsible party to initiate the cleanup and to carry out these activities until mitigation is completed to the satisfaction of the OSC. EPA has emphasized this by requiring contingency plans as part of the permitting requirements. The Coast Guard requires pollution response equipment to be available for oil transfer facility operations.

Local governments generally respond immediately to pollution incidents because of their close proximity and responsibility for public safety within their jurisdictions. In this regard, many city, county and state governments have created special hazardous material response teams to deal with and coordinate immediate "first aid" and mitigation of the public safety aspects of these incidents. However, federal authorities (EPA and Coast Guard OSCs) have responsibility to ensure that necessary actions are carried out to mitigate the effects of a spill in order to protect public health and welfare or the environment.

4. Coordination

There is ongoing close coordination between EPA and DOT. These two agencies coordinate the development of regulations, such as the adoption by EPA of DOT's regulations for transportation of hazardous wastes. These agencies have also agreed on a division of duties for enforcement, and have developed mechanisms for coordination, including formal agreements and processes for interagency review of proposed permits. Coordination with state and local agencies is achieved through the review process for proposed regulations and proposed permits, and through the National Contingency Plan.

Superfund and the Clean Water Act require the development of a National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which clearly delineates federal agency responsibilities for oil and hazardous materials pollution response activities. The NCP also mandates that this coordination and role identification be further documented for federal and state roles in Regional Contingency Plans. This coordination is continued at the local level in Local Contingency Plans, which describe the roles of state, county and municipal departments and the federal On-Scene Coordinator.

IV. DESCRIPTION OF INCINERATION TECHNOLOGY

This section provides an explanation of the technical aspects of land-based and ocean incinerators used for burning liquid hazardous waste. It describes the key design, performance and waste handling features, and discusses similarities, key differences, and major issues raised regarding the two technologies. Information presented here is taken from two sources: a background report, "Description of Incineration Technology," prepared by the Office of Management Systems and Evaluation; and the draft report on incineration by the Science Advisory Board.

Incineration technology has been used extensively for managing liquid organic hazardous wastes. A major benefit of incineration is that it destroys most of the waste, thereby vastly reducing the volume of waste that must be ultimately absorbed by the environment. Incineration can be used effectively for a variety of waste streams. Land-based incinerator systems have been applied for both on-site and off-site use, while ocean incineration systems are designed for off-site management of wastes.

On land, the most common types of hazardous waste incinerators currently in use are liquid injection and rotary kiln incinerators. The liquid injection incinerator, the most common type of hazardous waste incinerator on land, is also the type used in all ocean incinerator vessels. The rotary kiln with liquid capability is far less common, but is used by most major commercial land-based operators. For ocean incineration, the ship designs discussed are the Vulcanus I and II, owned by Chemical Waste Management, Inc., and the two Apollo ships being built for At-Sea Incineration, Inc. Two conceptual designs utilizing containerized systems are also discussed briefly. These systems have been proposed by Seaburn, Inc., and Environmental Oceanic Services, Inc.

A. INCINERATOR DESIGN

1. What is Incineration?

Incineration is a controlled oxidation process that uses flame combustion to combine hazardous wastes with oxygen, thus converting the wastes to less hazardous materials. The specific products of incineration vary depending on the types of wastes that are burned.

Incineration of simple, non-halogenated organic wastes involves the oxidation of carbon and hydrogen molecules to form carbon dioxide and water. If conditions for complete combustion are not present, carbon monoxide is also formed, but this product can be minimized by carefully controlling temperature, turbulence and oxygen during combustion. Because of this characteristic of the combustion process, the presence of excessive carbon monoxide in the flue gas is commonly used as a measure of incinerator performance.

Incineration of more complex organic wastes creates additional chemical products. Many industrial processes generate liquid hazardous wastes containing halogenated materials, with chlorinated compounds being the most common. (Halogenated compounds are those that contain the elements fluorine, chlorine, iodine, bromine, or astatine.) When chlorinated organic wastes are burned, the products include hydrogen chloride and small amounts of chlorine, as well as carbon dioxide and water. Other liquid hazardous wastes may contain metals, sulfur, or organically-bound nitrogen. When incinerated, they produce oxides of metals, sulfur and nitrogen.

An important consideration for hazardous waste incineration is the heating value of the wastes. To maintain stable combustion, the heat released from burning wastes must in turn be able to ignite incoming wastes, thus providing the energy needed for oxidation to occur. The heating value of an organic waste decreases as the percentage of water or chlorine increases. Liquid wastes with low heating values require auxiliary fuel or blending with wastes that have higher heating values.

2. Basic Design Features for Land-Based Incinerators:

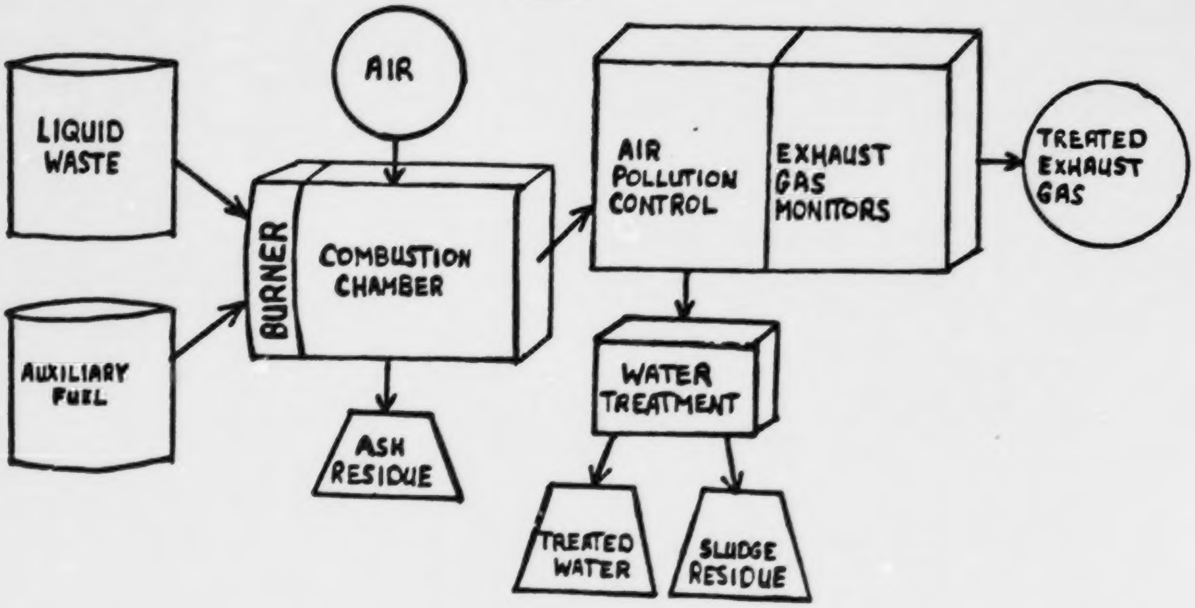
All waste incinerators on land consist of a waste feed system, an air or oxygen-fed burner system, a combustion chamber, combustion monitoring systems, and, if required, equipment for air pollution control and ash removal. (The simplified flow diagram in Figure 1 illustrates the relationships of these basic elements of incinerator design.) These elements are applied somewhat differently in liquid injection and rotary kiln systems.

The liquid injection system is capable of incinerating a wide range of liquids, gases and slurries. The combustion system has a very simple design with virtually no moving parts. A burner or nozzle atomizes the liquid waste and injects it into the combustion chamber where it volatilizes and is incinerated. A forced draft system supplies the combustion chamber with air to provide oxygen for combustion and turbulence for mixing. The combustion chamber is usually a cylinder lined with refractory (i.e., heat resistant) brick, and may be fired horizontally, vertically upward, or vertically downward. The specific configurations are designed to satisfy the needs of the owner.

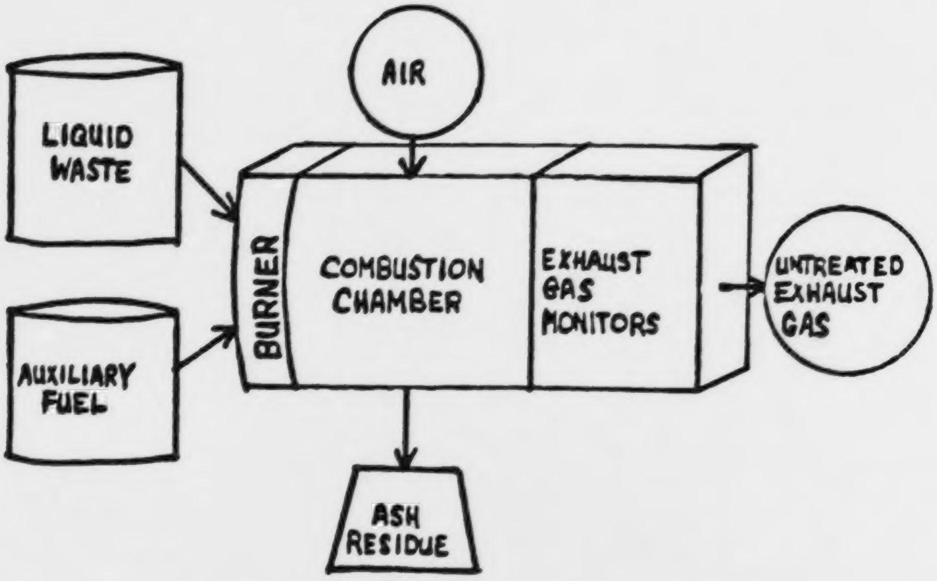
Rotary kiln systems are capable of incinerating solid, sludge, liquid and gaseous hazardous wastes either separately or simultaneously. In general, commercial rotary kiln operators utilize high Btu liquid wastes in conjunction with lower Btu solids in order to enhance combustion. Because of their

FIGURE 1: COMPARISON OF A GENERALIZED INCINERATION SYSTEM ON LAND AND OCEAN

LAND


AIR
LIQUID WASTE
AUXILIARY FUEL
BURNER
COMBUSTION CHAMBER
ASH RESIDUE
AIR POLLUTION CONTROL
EXHAUST GAS MONITORS
TREATED EXHAUST GAS
WATER TREATMENT
TREATED WATER
SLUDGE RESIDUE

OCEAN


AIR
LIQUID WASTE
AUXILIARY FUEL
BURNER
COMBUSTION CHAMBER
EXHAUST GAS MONITORS
UNTREATED EXHAUST GAS
ASH RESIDUE

versatility, rotary kilns have been used for large commercial facilities. A rotary kiln is a slowly rotating, refractory-lined cylinder that is mounted at a slight incline from the horizontal. Solid wastes enter at the high end of the kiln, and liquid or gaseous wastes enter through atomizing nozzles. Rotation of the kiln exposes the solids to the heat, vaporizes them, and allows them to combust by mixing with air. The rotation then causes the ash to move to the lower end of the kiln where it can be removed. Rotary kiln systems usually have a secondary combustion chamber or afterburner following the kiln to ensure more complete combustion of the wastes.

3. Basic Design Features for Ocean Incinerators

Ocean design also utilizes liquid injection incinerators. Design elements include a waste feed system, a combustion air or oxygen system, a combustion chamber and combustion monitoring systems. Ocean incinerators do not have equipment for air pollution control. Figure 1 illustrates the relationships of these basic elements.

The Vulcanus ships employ vertically-mounted liquid injection incinerators, each having three rotary cup vortex burners, firing into a cylindrical, refractory-lined combustion chamber. The Vulcanus I has two incinerators mounted on its stern, and the Vulcanus II has three incinerators. The Apollo ships will each be equipped with two vertically-mounted liquid injection incinerators in the stern. The Seaburn design would make use of an oceangoing barge, towed by a tug, and carrying 144 mobile stainless steel containers stored above the main deck in vertical cells. Incineration would be provided by two horizontally-mounted liquid injection incinerators.

4. Design Issues

The major issues directly related to design are discussed below. Note that there are several significant differences between land-based and ocean incineration design. (Table 1 provides a comparison of key design features.)

- Atomizing Burner

  Maintaining atomizing burners in good operating condition is an issue for both land and ocean incinerators. In normal operation, atomizing burners in liquid injection incinerators are subject to corrosion and plugging which may impede atomization. Several measures should be taken to prevent this from occurring: (1) selection of a design appropriate to the specific incinerator geometry and waste characteristics, and (2) frequent visual inspection, monitoring of feed pressure, and cleaning and replacement when necessary.

TABLE 1: COMPARISON OF KEY DESIGN FEATURES

DESIGN FEATURES	LAND-BASED		OCEAN			
	LIQUID INJECTION	ROTARY KILN	VULCANUS I	VULCANUS II	APOLLO	CONTAINER VESSEL DESIGNS
Burns Liquids	Yes	Yes	Yes	Yes	Yes	Yes
Burns Solids, Sludges	No	Yes	No	No	No	No
Combustion System Design	Liquid is atomized and incinerated in fine droplet form.	Solids fed at high end and rotated through. Liquids fed through atomizing nozzles or lances.	Liquid is atomized and incinerated in fine droplet form.			
Combustion Chamber	Fixed cylindrical chamber. Refractory-lined.	Rotating cylindrical chamber. Refractory-lined.	Fixed cylindrical chambers. Refractory-lined.			
Afterburner (Secondary Burner)	May have	Generally used to ensure complete combustion	No	No	No	No
Supplementary Fuel Used	Can be fed in depending on nature of wastes being burned.					
Number of Incinerators Per Facility	Variable	Variable	2 incinerators	3 incinerators	2 incinerators per ship	Variable
Waste Feed Rate (Gallons/Hour)	Range:<50 to 1000 Median: 150	Range: <50 to 2000	1650 per incinerator 3300 Total	4950 Total	2750 per incinerator or 5500 per vessel	Variable
Air Pollution Controls	Usually will have control devices for acid gases and particulates. Must meet performance standards.		None	None	None	Seawater scrubber to dilute plume
Treatment of Residuals and Scrubber Water	Scrubber and residuals must be managed as a hazardous waste.		No scrubber water.			Scrubber water goes directly into ocean.
			Residuals reincinerated or returned to land.			
Combustion Zone Temperature °C	815-1240	815-1240	1166-1600		Not yet demonstrated	
Heat Recovery	About 25% of incinerators employ heat recovery	About 30%	None	None	None	None

Some critics have claimed that the rotary cup burners employed by the Vulcanus are inadequately designed to ensure complete combustion. EPA believes this criticism is unfounded. Industry burner designs vary greatly, and EPA has measured acceptable incinerator performance for a wide range of burner designs, including the rotary cup burner observed throughout the Vulcanus monitoring activities. Consequently, EPA has focused regulation on incinerator performance rather than burner design.

- Combustion Chamber

A few critics of the Vulcanus have argued that the combustion chamber design is inadequate because it does not provide sufficient turbulence for mixing of the waste with oxygen or enough residence time for complete combustion. EPA believes that the appropriate test of any incinerator system, including the Vulcanus, is its performance characteristics rather than the design features. EPA has evaluated a wide range of chamber designs with varying residence times and has found that most of them will perform satisfactorily with proper operating temperatures, feed rates, and maintenance. Although chamber design affects performance, no clear formula exists for linking any particular chamber design to destruction efficiency.

- Pollution Control Devices

Land-based incinerator design generally incorporates scrubbers to meet particulate and acid gas standards. As a result, acid gas and particulate emissions are reduced, but scrubber water is generated and must be managed as a hazardous waste.

Since ocean incinerator design on the Vulcanus and Apollo ships does not include scrubbers, there is no scrubber water to be managed. The proposed designs by Seaburn and Environmental Oceanic would be equipped with seawater quench devices which only serve to dilute the plume and cause it to mix with the sea more rapidly. Critics claim that the lack of scrubbers results in the release of acid gases and particulates which may endanger the environment and human health. Monitoring from previous burns as well as modelling indicates that acid gases are adequately neutralized by the ocean and that particulate emissions can be kept at safe levels by requiring limits on the metal content of the wastes to be incinerated.

- Heat Recovery

Approximately 25 percent of land-based incinerators currently employ heat recovery equipment, while ocean incinerators do not. Critics claim that ocean incineration therefore results in a loss of potential energy. Ocean incineration design does not include mechanisms for heat recovery because the energy that would be generated could not be utilized at sea, and because the high concentration of hydrogen chloride (HCl) in ocean incinerator emissions would damage heat recovery equipment. Major land-based commercial competitors for highly chlorinated wastes also do not currently employ energy recovery.

B. INCINERATOR PERFORMANCE

1. The Concepts of Destruction Efficiency and Destruction and Removal Efficiency

EPA believes that incinerator efficiency is best determined by the ability to achieve acceptable performance levels, and not by incinerator design. The performance-based system is used largely because there are a wide variety of incinerator designs which are capable of adequately destroying wastes when properly operated and maintained.

Performance of hazardous waste incinerators is normally measured in terms of destruction efficiency (DE) or destruction and removal efficiency (DRE). Destruction efficiency refers to the percentage of hazardous constitutents destroyed in the combustion chamber, while destruction and removal efficiency accounts for both the destruction in the combustion chamber and removal of remaining original hazardous constituents by air pollution control equipment. The RCRA regulations require a DRE for most principal organic hazardous constitutents (POHCs) of 99.99%, while the proposed ocean incineration regulations require a DE of at least 99.99% for most POHCs. The DE required for incineration of polychlorinated biphenyls (PCBs), dioxins, and dibensofurans is 99.9999%.

2. The Principal Organic Hazardous Constituents (POHCs) System

Because many of the liquid hazardous wastes to be incinerated are complex mixtures of many different compounds, the RCRA program developed a system whereby the overall performance of an incinerator is measured by tests on a small number of waste constituents or individual hazardous compounds. The Office of Water has also adopted this approach for the ocean incineration program.

The testing system uses a small number of principal organic hazardous constitutents to represent the many compounds found in a complex waste. In order to use POHC surrogates to represent many compounds, EPA developed a system to rank compounds on the basis of how difficult they are to burn. Incinerability is measured by "heat of combustion," a theoretical calculation of energy released when waste molecules are combusted. Compounds with a lower heat of combustion are presumed to be more difficult to burn than those with a higher heat of combustion.

Some persons have questioned the utility of the POHC system, and particularly the heat of combustion index. They claim that it does not allow adequate determination to be made of the incinerability of complex mixtures of chemical compounds. In addition, recent data obtained by the Office of Research and Development (ORD) does not substantiate the heat of combustion and concentration-based method for ranking compounds. Evidence seems to be mounting that any or all organics may be destroyed essentially equally under a given condition.

The issue of selecting the appropriate measure for a POHC ranking system becomes less important when one considers that normal operating temperatures which organic compounds are subjected to in land and ocean incinerators are several hundred degrees higher than temperatures needed to destroy any compounds at the top of all investigated or considered hierarchies. EPA is continuing to assess the reliability of this system, but believes it to be the best system currently available.

3. Performance Results for Land-Based Incinerators

Past test results from land-based incinerators show that performance levels for DRE on compounds chosen as POHCs and on PCBs are achievable.

During the 1970's, EPA conducted a series of test burns in land-based incinerators to measure destruction efficiency. The tests involved liquid injection and rotary kiln incinerators (as well as other thermal technologies), and demostrated that 99.99 percent DE was achievable. These test burns became the basis for the selection of the 99.99 percent DRE standard in the RCRA regulations.

In order to develop further information on incinerator performance in conjunction with an incinerator Regulatory Impact Analysis (RIA), EPA conducted additional test burns. The tests involved a wide variety of incinerator designs, control devices, waste types, and operating conditions. These second test burn results provide strong additional support for the capability of achieving DREs of 99.99 percent.

Because the RIA tests only measured performance for short periods during optimum operating conditions, the Science Advisory Board recommended that EPA examine more closely the frequency and effects of "upset conditions" which might result in increased emissions to the environment. In 1985, EPA is conducting a series of tests at its Combustion Research Facility in Arkansas which will address this issue. A series of research burns will provide information on emissions under abnormal or "off-design" conditions which might occur from waste composition anomalies or mechanical failures. In addition, current permitting guidance recommends that trial burns conducter for permitting be extensive enough to include short-term suboptimal conditions. Permit conditions therefore include temperature and other requirements to assure a DRE greater than 99.99% for continuous operating conditions rather than short-term optimal conditions. Long-term upset conditions require termination of hazardous waste fuel until the upset condition is corrected.

Data from many trial burns of liquid polychlorinated biphenyls provide evidence that the thermal destruction of PCBs in incinerators, in accordance with PCB regulations, can be accomplished with efficiency and minimal emissions of undestroyed PCBs. These trial burns have demonstrated that incinerators with a variety of designs can achieve a destruction efficiency of greater than 99.9999% for PCBs.

4. Performance Results for Ocean Incinerators

Since 1974, the Vulcanus I has been involved in four series of test burns under the Ocean Dumping Regulations. EPA participated in an additional series of test burns for the Vulcanus II held in the North Sea in 1983. EPA scientists believe the test burn results indicate that destruction efficiencies of greater than 99.99% are achievable. For example, an August 1982, Vulcanus I test burn in the Gulf of Mexico of an organochlorine mixture showed DEs greater than 99.99 percent for several POHCs, including hexachlorobenzene, the POHC with the lowest heat of combustion of those tested. Similarly, a February 1983 test burn for the Vulcanus II in the North Sea resulted in DEs of greater than 99.99 percent for several POHCs, including carbon tetrachloride. Tables 2 and 3 provide more details on the test burns.

Many past test burn results have been questioned because of the sampling practices and analytical methodologies used. This issue is addressed under sampling and monitoring.

5. Products of Incomplete Combustion (PICs)

In the process of combustion, whether burning hazardous wastes or fossil fuels, incinerators and other combustion devices may cause the formation and emission of potentially harmful substances that are not present in the initial waste feed. Concern about the creation of these substances, called products of incomplete combustion (PICs), became acute in the late 1970's with the discovery of chlorinated dioxins and furans in the emissions of many incinerators burning municipal refuse and hazardous wastes.

Because of the potential hazard from emissions of chlorinated dioxins or furans, EPA has studied this issue closely. In 1980, EPA sampled five municipal incinerators

Table 2: VULCANUS I TEST BURNS*

	(1)	(2)	(3)	(4a)	(4b)
DATE	October 1974 - January 1975	March 1977	July - September 1977	December 1981- January 1982	August 1982
LOCATION	Gulf of Mexico	Gulf of Mexico	Johnston Atoll, Pacific Ocean	Gulf of Mexico	Gulf of Mexico
WASTES AND COMPOUNDS BURNED	Chlorinated hydrocarbons	Chlorinated hydrocarbons	Herbicide Orange (2, 4-D; 2, 4, 5-T; 2, 3, 7, 8 TCDD)	PCBs, TCDF chlorobenzenes	PCBs, TCDF chlorobenzenes
QUANTITY BURNED	16.8K metric tons	12.3K metric tons	10.4K metric tons	3.5K metric tons	3.5K metric tons
DE DATA ACCEPTABLE?	NO	NO	YES	NO	YES
DEs REPORTED	"Organochlorides" >99.9%	Trichloropropane (C_3Cl_3) 99.92% - 99.98%	Dioxin (TCDD) > 99.93% 2, 4 - D >99.999% 2, 4, 5 - T >99.999%	EPA calls results inconclusive due to inadequate amount of valid data obtained	PCBs > 99.999% TCDF > 99.93% Hexachlorobenzene > 99.99%

* Sponsored by EPA. Other test burns have been conducted in the North Sea.

Table 3: VULCANUS II TEST BURNS

	(1)	(2)
DATE	January 22-30, 1983	February 14-19, 1983
LOCATION	North Sea	North Sea
WASTES BURNED	Liquid Organochlorines	Liquid Organochlorines
QUANTITY BURNED	Not stated	1000 metric tons
DE DATA ACCEPTABLE?	No	Yes
DEs	EPA determines published DEs are unusable since approved analytical protocol was not followed	CCl_4 >99.99% $CHCl_3$ >99.99% 1,1,2-TCE >99.99% 1,2-DCE >99.99% 1,1-DCE >99.99%

for dioxin emissions and found both the emissions and human health risk from the emissions quite low. At the same time, EPA evaluated the formation of dioxins and furans during the incineration of PCBs at the ENSCO and Rollins incinerators in El Dorado, Arkansas, and Deer Park, Texas. Although low levels of both PICs were found, a worst case risk analysis showed the incremental human health risk for cancer to be in the range from 0.1 to 0.8 per million population, based on the point of maximum ambient air concentration in a residential area. EPA also examined PIC formation during the test burns conducted in 1981 for the Regulatory Impact Analysis. In ocean test burns, EPA found only trace amounts of dibenzofurans, and in one instance, dioxin at 0.09 nanograms per cubic meter. Other potential PICs were not investigated.

Because studies to date indicate that reported levels of PICs from well operated incinerators present very low risks, EPA has not regulated PICs. However, everyone agrees that more information on PICs is needed. In particular, the Science Advisory Board report recommends that EPA take steps to characterize incinerator emissions more completely, specifying the identity of all chemicals released to the environment. A more comprehensive characterization of emissions would provide an improved estimate of risks for both land and ocean incineration. The risk assessment prepared for this study does analyze the risks from PICs, but the available studies did not provide the degree of characterization recommended by the SAB.

Both the RCRA program and ORD are continuing research into the factors affecting PIC formation and control, and the potential effects of PICs on human health and the environment. The ocean incineration program is proposing that measurement and analysis of PIC emissions be done during research permit burns.

C. SAMPLING AND MONITORING

1. Monitoring to Determine Compliance with Performance Standards

For both ocean and land-based incinerators, compliance related sampling and monitoring involves two phases: the trial burn and normal operations.

Comprehensive sampling and monitoring is conducted during a trial burn to determine the range of operating parameters for which the incinerator is capable of achieving the required performance levels. Sampling techniques and analysis methods must be in accordance with 40 CFR part 60, Appendix A (Methods 1-5), and Text Methods for Evaluating Solid Waste: Physical/ Chemical Methods (SW-846, Second Edition, July 1982), or in

Sampling and Analysis Methods for Hazardous Waste Combustion (A.D. Little, Inc., EPA-600/8-84-002, February 1984). In order to calculate destruction efficiency, the mass input and emissions of POHCs are measured. In addition, key operating factors such as temperature, carbon monoxide emissions, and waste feed rate are determined. Land-based incinerators also require monitoring sufficient to provide computation of particulate emissions and hydrogen chloride (HCl) removal efficiency (if emissions exceed 1.8 kilograms HCl per hour).

Based upon the results of the trial burn, final operational parameters are established. The permit designates operating requirements which are specific to each waste feed burned, and which reflect the range of operating conditions shown to achieve acceptable performance levels. During normal operations, concentration and mass emissions of POHCs are not measured, but indicators such as temperature and carbon monoxide are measured continuously. Due to London Dumping Convention requirements, there are slight variations in the parameters monitored on land and at sea.

An important safety feature of both land and ocean systems is the required automatic waste feed cutoff system which shuts off the waste feed to the incinerator whenever certain operating parameters deviate from the limits set in the permit. Both the land and ocean program require frequent testing of the cutoff systems.

Questions have been raised as to whether state-of-the-art techniques for emissions sampling, analysis and monitoring have been used on ocean incinerators, and whether or not these procedures are actually applicable to ocean incinerators due to short stacks and high stack gas temperatures. In evaluating past burns, EPA scientists believe that destruction efficiency data is acceptable based on present technology for only three of the burns. In earlier burns, proper destruction efficiencies may have been achieved, but sampling and analysis techniques used then did not provide sufficient information based on current standards of evaluation.

The draft research strategy prepared by the Office of Water addresses three technical areas where additional analytical studies should be conducted during research burns. The first is more vigorous testing of performance through longer sampling times, traversing the stack, and quantifying particulate patter. The other areas of concern are a more complete characterization of emissions and potential chemical changes as hot effluent gases enter the cooler atmosphere.

2. Ambient Monitoring

Under RCRA and TSCA, no ambient monitoring is required for land-based incinerators. All routine monitoring is for stack emissions. In some cases, states may require ambient monitoring under the Clean Air Act.

Based upon risk studies, EPA scientists believe that if stack emissions are within regulatory limits, there will be no adverse environmental effects. Furthermore, EPA scientists believe that accurate and reliable testing for ambient air effects around land-based incinerators is generally not feasible due to extremely low concentrations and interference from other industrial activities.

For ocean incineration, some environmental studies have been conducted during past ocean burns. EPA has used ships and planes to follow and sample incinerator plumes in order to model the dispersion of the emissions over the ocean, and water samples were analyzed for possible emission constituents. Organisms have also been caged in the incinerator ship area to determine if any effects could be observed. In these studies, EPA has not detected any increase in background levels of any emission products in ambient air, water, or marine biota samples collected.

In its review of the scientific literature on incineration, the Science Advisory Board acknowledged the difficulty of linking environmental effects to incinerator emissions through field monitoring, particularly because of the widespread burning of fossil fuels for heating, transportation and industrial processes. Also, the SAB agreed with EPA that there is as yet no evidence that the operation of liquid hazardous waste incinerators has produced adverse ecological effects. At the same time, however, the SAB encouraged EPA to expand its work on the transport, fate, and effects of incinerator emissions by using a combination of laboratory and field studies. The draft research strategy for incineration at sea developed by the Office of Water embodies many of the approaches suggested by the SAB.

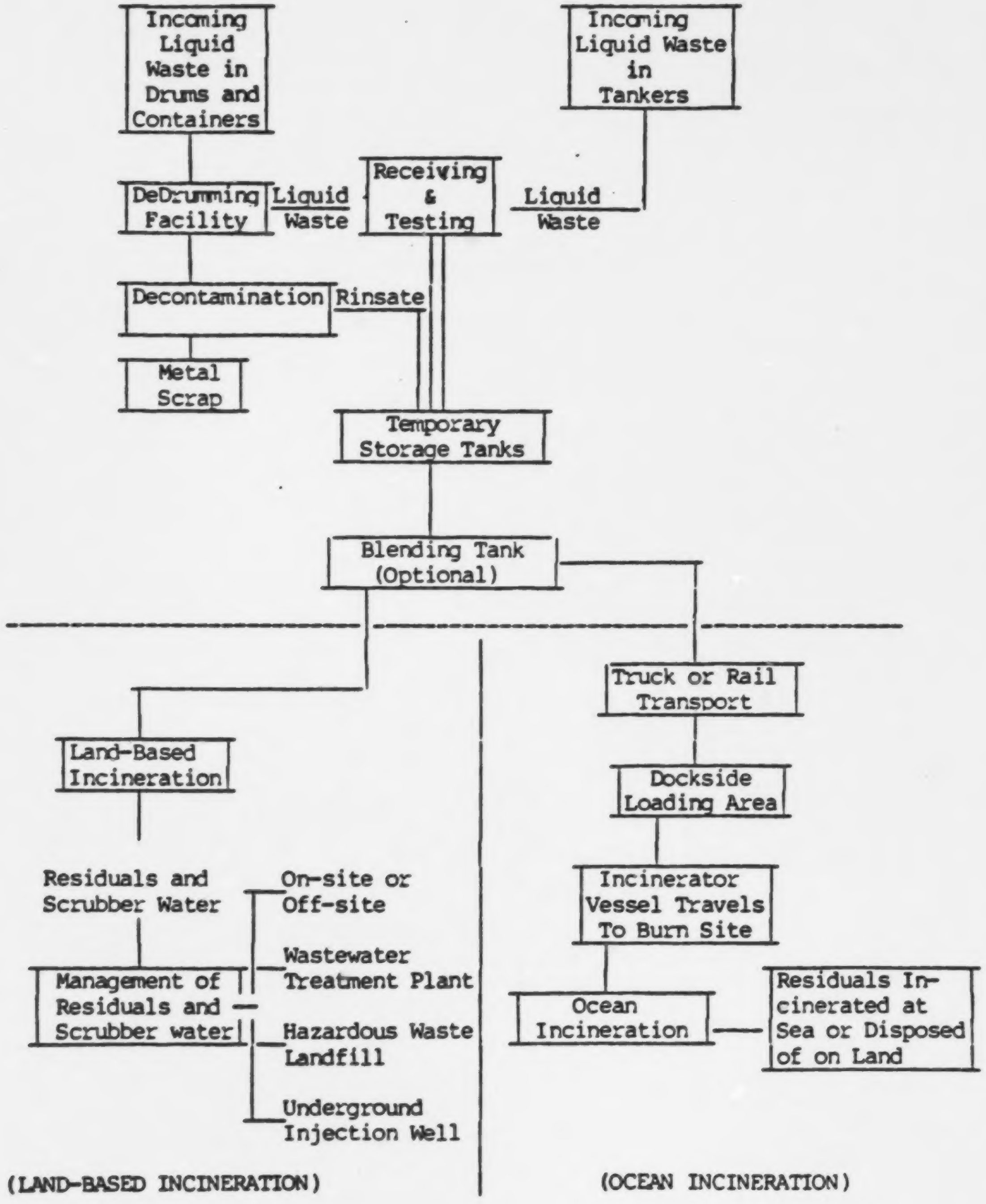
D. WASTE HANDLING

1. Waste Handling Aspects of Land-Based Incineration

Figure 2 illustrates a typical process flow for a land-based commercial incinerator. In practice, many variations occur, especially among on-site and smaller facilities. In this illustration, incoming wastes are delivered to the facility either as liquids in tank trucks or in drums and other types of containers. If the wastes have not been previously identified, they are tested to determine content, viscosity, and combustion value. Then the wastes are pumped into temporary storage tanks which are set up to accommodate compatible waste streams. Some incinerator operations may also utilize a blending tank to prepare an optimal mixture for burning.

When incineration begins, wastes are pumped from the storge tanks or the blending tank to the incinerator at feed

Figure 2: Simplified Process Flow for a Land-Based Incinerator and an Existing Infrastructure Ocean Incineration System


Incoming Liquid Waste in Drums and Containers
Incoming Liquid Waste in Tankers
DeDrumming Facility
Liquid Waste
Receiving & Testing
Liquid Waste
Decontamination
Rinsate
Metal Scrap
Temporary Storage Tanks
Blending Tank (Optional)
Truck or Rail Transport
Land-Based Incineration
Dockside Loading Area
Residuals and Scrubber Water
On-site or Off-site
Incinerator Vessel Travels To Burn Site
Wastewater Treatment Plant
Management of Residuals and Scrubber water
Residuals Incinerated at Sea or Disposed of on Land
Ocean Incineration
Hazardous Waste Landfill
Underground Injection Well
(LAND-BASED INCINERATION)
(OCEAN INCINERATION)

rates which provide for optimum combustion and which do not exceed the maximum thermal input (BTU per hour) allowed by the permit. If necessary, supplementary fuel is fed into the incinerator to enhance combustion.

Following incineration, scrubbers are employed to remove acid gases and particulates before they can be released from the stacks. The process creates scrubber water which is classified as a hazardous waste. Options for managing the scrubber water include underground injection wells, treatment and release to surface waters under an NPDES permit, and settling and removal of sludge for disposal in a hazardous waste landfill.

2. Waste Handling Aspects of Ocean Incineration

Three logistical systems have been proposed for managing waste handling aspects of ocean incineration. These are no-infrasturcture, integrated, and existing infrastructure systems.

- No-Infrastructure System: This system minimizes the use of fixed facilities. Wastes accumulate at their sources and are stored in truck or rail tanks or portable liquid containers. Filled containers are transported to an existing port transfer facility which is not dedicated solely to incinerator ship operations. The wastes are then pumped or the containers lifted directly onto vessels. With portable containers, each container has a direct feed to the incinerator, and the wastes never leave the container until actual incineration of the wastes begins at sea.

- Existing Infrastructure System: An existing infrastructure system is similar to a no-infrastructure system in that it makes use of port transfer facilities which are not dedicated solely to incinerator ship operations. It differs from the no-infrastructure system primarily in that it allows for blending, preparation, and storage functions to be performed at existing, centralized facilities which are separate from the port facility. Figure 2 illustrates a process flow for ocean incineration using an existing infrastructure system.

- Integrated System: An integrated system involves the siting of a specialized port facility dedicated primarily to incinerator ship operations. The facility receives waste from generators and has the capacity for analyzing, blending, and storing them.

3. Key Differences in Waste Handling

Although there are many variations among the different systems, the key differences between ocean and land-based incineration are in the transport of the wastes and disposal of residuals.

On land, the wastes are pumped directly from the blending tanks or temporary storage tanks to the incinerator. In contrast, an existing ocean infrastructure system, such as that proposed for the Vulcanus, would require an additional transfer and transport leg to haul wastes from the blending site to the port site. In all of the ocean systems there is an additional transportation step from the port site to the ocean burn site.

The other key handling differences are in the disposal of residuals. Land-based facilities must handle scrubber water resulting from their processes. Current ocean incineration operations are not faced with managing scrubber water, since they do not use scrubbers. Under the proposed SeaBurn system there is still no scrubber water residual, since sea water used in the quench system is returned directly to the ocean.

4. Key Waste Handling Issues

Critics are concerned that the mixing of incompatible waste could lead to runaway chemical reactions, fires or explosions, but compatibility tests are a routine part of system safeguards for land and ocean operations.

For example, in preparation for ocean incineration, Chemical Waste Management (CWM) routinely tests incoming waste for blending compatibility at its facility in Emelle, Alabama. Only after the wastes are found to be compatible are they blended. CWM reports that blended wastes are held in storage tanks for a minimum of several days before loading into tank trucks for transport to the Vulcanus. Any reaction that could occur would occur by this time.

For land-based incinerators, permits indicate the scope and frequency of sampling of incoming waste to determine whether it is within permit-specified physical and chemical composition limits, and to prevent the mixing of incompatible wastes. It is in the best interest of land and ocean incinerator operators to ensure that adequate testing of incoming waste is done as a safeguard to protect their own investments.

An additional concern involves the potential for spills and fugitive emissions during the collection, transport, pumping, and storage of the wastes. In the absence of concrete data, the SAB and others have speculated that releases from handling and storage might be large. The risk assessment conducted for this study, however, indicates that such releases are probably very small compared to stack emissions.

E. CONTINUING AND PLANNED RESEARCH

The Agency's Office of Research and Development has a continuing incineration research program that is applicable to land and ocean incineration. This program focuses on destruction efficiency through extensive field testing on different types and sizes of incinerators. Through this research, extensive incinerator performance data have been developed in support of RCRA regulations, regulatory impact analyses, and Regional and State programs.

The goal of this research program is to fulfill the need for scientific and operating data to assure compliance and safe operation of thermal destruction systems on land and at sea. Specific efforts include the following:

- Work is continuing on assessing performance capabilities of existing hazardous waste thermal destruction devices (incinerators, industrial kilns, boilers, etc.). Resulting data will provide additional technical grounding for Agency policies and regulations on thermal destruction as a hazardous waste disposal option.

- Research underway at the EPA Combustion Research Facility (CRF) in Arkansas and at the EPA Center Hill research facility in Cincinnati is developing an understanding of thermal destruction chemistry and the engineering of thermal processes. This is a first step in characterizing and assessing the performance of full-scale thermal destruction devices and in extrapolating performance information from one waste or scale of equipment to another.

- Laboratory and limited field evaluation of stack-gas sampling trains for volatile organics will be done, and methodologies updated. In addition, a stack sampling train for semi-volatile organics will be evaluated, and the revised method validated.

- In early 1985, the Arkansas facility will embark on a series of burns of typical liquid and solid organic hazardous waste streams to determine the emissions under abnormal or "off-design" conditions, such as transient conditions which can occur during startup, shutdown, waste composition anomalies, or mechanical failures.

- Work will be done to define easily monitored incinerator operating parameters which correlate with system performance. This will allow rapid, reliable, and economical determination by enforcement officials of compliance with permit conditions, and facilitate preventive or corrective actions.

- Efforts will continue to investigate the performance capabilities of innovative thermal destruction processes which may be capable of handling hazardous wastes not suitable for current systems, more cost effective than current systems, or capable of attaining higher or more reliable performance than existing processes.

In addition to this general research program, EPA's Office of Water has developed a research strategy specifically directed at gathering additional scientific information related to incineration at sea. This strategy, completed in February 1985, will provide direction to EPA's ocean incineration research program, including research burns which are expected to begin in the summer of 1985. These burns will provide opportunities for more complete emissions characterization, evaluation of emissions toxicity, additional testing and validation of emissions monitoring methods, further analysis of plume dispersion, and environmental monitoring at the burn site.

The Science Advisory Board's review of past incineration research efforts also resulted in a series of recommendations for gathering additional or improved information. The SAB notes that incineration is a valuable means for destroying hazardous wastes and that its recommendations are designed to strengthen the already existing programs. The major focus of the SAB report is the development of additional information to refine EPA's analyses of the potential impacts of incineration on human health and the environment. For example, the SAB recommends that future research activities include:

- A more complete identification of emissions, including their physical form and important characteristics;

- An assessment of releases to the environment from all phases of incineration operations, including waste handling and transportation;

- Further validation of sampling methodologies;

- Improving simulations of atmospheric and aquatic transport and fate of emissions, including better use of local meterological conditions and consideration of possible ocean microlayer impacts;

- Additional efforts to analyze the toxicities of incinerator emissions, including laboratory toxicity studies and field assessments.

In general, these recommendations are consistent with EPA's current and planned research efforts described previously. In addition, the risk assessment prepared for this study addresses in detail the SAB concern with releases during transport, storage, and handling phases of incinerator operations.

V. MARKET CONSIDERATIONS FOR INCINERATION

This section presents an overview of current and future conditions of the market for incineration of liquid organic hazardous wastes (LOHWs). It profiles the current market, establishing baseline estimates for volumes of LOHWs presently incinerated, and estimates the degree to which existing incineration capacity is currently being utilized. Also presented are projections of incineration demand and capacity in response to possible changes in the RCRA regulations. finally, alternative technologies are assessed in order to judge their comparability to incineration for managing LOHWs, and their possible effects on the market for incineration.

Information contained in this section is taken from the background report, "Assessment of the Commercial Hazardous Waste Incineration Market," prepared by Booz, Allen and Hamilton Inc. for EPA's Office of Policy Analysis, and from the background report, "Assessment of Alternative Technologies," prepared by EPA's Office of Research and Development.

A. ASSESSMENT OF THE COMMERCIAL HAZARDOUS WASTE INCINERATION MARKET

Two key limitations of the market assessment should be kept in mind when evaluating and using these results. First, this market assessment has been conducted only at the national level, although a regional analysis would have increased the usefulness of the results. But the limited sample size of the database prevented an analysis of regional impacts of land disposal restrictions and other RCRA amendments - impacts that might vary significantly by Region.

Secondly, the numerous sources of data used were often inconsistent or not in an easily accessible form. The principle source of data was the National Survey of Hazardous Waste Generators and Treatment, Storage, and Disposal Facilities Regulated Under RCRA in 1981. This was supplemented with other reports, discussions with EPA staff, and contacts with leading firms in the hazardous waste management industry. Attempts were made to reconcile and corroborate estimates and assumptions, but this was not always possible, so we have often had to use ranges rather than exact numbers. The study does, however, reflect a general consensus that estimates and assumptions are reasonable.

Each of these limitations to the study may be overcome in the future as more and better data become available to the Agency.

1. Profile of the Incineration Market

According to EPA's 1981 survey of hazardous waste generators, about 264 million metric tons (MMT) of solid and liquid waste were generated that year. Less than one percent of these wastes were liquid wastes that were incinerated. Of the total liquid waste incinerated, only about ten percent, or .14 MMT, was burned at off-site commercial facilities, while ninety percent were incinerated by the generators.

Estimates of commercial* incineration facilities range from 25 to 40, with 30 used as the best estimate for this analysis. There are approximately 200 to 210 on-site or captive incineration facilities. Because some facilities may have multiple incinerators, estimates of the number of operating incinerator units is somewhat higher: 30 to 50 commercial and 240 to 290 on-site.

Most of the incineration facilities are located in the Southwest and Southeast; however, commercial firms in the Middle Atlantic and North Central regions of the country have significant capacity. Very few firms are located in the Western U.S.

Liquid injection units are the most common type of incinerator, but newer units tend to be rotary kilns or fume incinerators. Precise estimates of throughput capacity are difficult to make due to lack of information and different ways of defining throughput. One data source shows that of operational liquid hazardous waste incineration units, 55% have capacity of up to 200 gallons per hour, 39% have capacity of 201-2000 gallons per hour, and 5% have capacity of 2001-10,000 gallons per hour.

Estimates of volumes of LOHWs currently incinerated vary depending on the source. The estimated quantity used for this analysis is 1.392 million metric tons (MMT) per year. Most of this amount is accounted for by three waste code categories: miscellaneous commercial chemical product wastes, ignitable wastes, and solvents. There is general agreement between industry sources and the RIA National Survey data that about 90% of these wastes are incinerated on-site and 10% off-site.

Industry sources view commercial incineration as becoming increasingly cost-competitive with land disposal due to changes in the RCRA program and potential long-term liability costs associated with land disposal. Industry also envisions a trend toward increased competition among commercial incineration firms to capture larger market shares.

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*As used in this report, the terms "commercial and "off-site" are synonomous.

Incineration firms cited public opposition and regulatory permitting requirements as being the most significant barriers to market entry, creating 3 to 5 year delays in bringing new incinerators on-line. Large capital investment was also cited as a potential barrier.

There is a lack of consistent information on unit costs of incineration and other current hazardous waste management practices. Unit costs vary widely depending on such factors as: 1) the physical state, the Btu content, ash content, and the toxicity of the particular waste 2) the form of the waste (i.e. drum versus bulk), and 3) the competition at the regional level among alternative waste management facilities.

Reliable estimates of costs for ocean incineration are further complicated because the availability of ocean incineration capacity has not yet been firmly established in the commercial market. For all hazardous waste management practices, costs are also affected by changes in the Federal regulatory program.

The following table presents very rough unit cost figures for various waste management practices and is useful only for making general comparisons.

Type of Waste Management	Type or Form of Waste	Price 1981 $/metric tonne
Landfill (a)	- Drummed	$ 168 - 240
	- Bulk	$ 55 - 83
Deep Well Injection (a)	- Oily wastewater	$ 16 - 40
	- Toxic rinse water	$ 132 - 264
Chemical Treatment (a)	- Acids/alkalines	$ 21 - 92
	- Cyanides/heavy metals, and highly toxic waste	$ 66 - 791
Land Incineration (a)	- Liquids	$ 53 - 237
	- Solids and highly toxic liquids	$ 395 - 791
Ocean Incineration (b)	- Chlorinated hydrocarbons	$ 200 - 250
	- Polychlorinated biphenyls	$ 500 - 800

a. Source: Booz, Allen and Hamilton, Inc.- Based on interviews conducted with major commercial firms in February 1982.

b. Source: Kidder, Peabody and Company, Inc.- Based on Kidder, Peabody estimates, April 1982.

2. Baseline Incineration Capacity and Demand

Baseline capacity utilization estimates suggest that available on-site and commercial incineration capacity for LOHWs is not fully utilized. Both on-site and commercial incineration capacity utilization may vary from 40 to 80 percent depending upon the baseline estimate used for quantities of waste incinerated. For the market assessment, low, mid-range and high estimates were used. The following conditions of baseline supply and demand reflect the mid-range estimates.

o Demand:

-Total quantity of LOHWs incinerated = 1.392 MMT/year
-On-site/off-site split = 90% on-site/10% off-site
-Total quantity incinerated on-site = 1.253 MMT/year
-Total quantity incinerated off-site (including PCBs) = 0.139 MMT/year

o Capacity (Supply):

-Total LOHW Incineration Capacity = 3.4 MMT/year
-On-site/off-site split = 91.2% on-site/8.8% off-site
-Total on-site LOHW incineration capacity = 3.1 MMT/year
-Total off-site LOHW incineration capacity (including PCBs) = 0.252 MMT/year

o Capacity Utilization:

-On-site capacity utilized = 40%
-Off-site capacity utilized = 55%

For PCBs alone, it is estimated that 48,368 metric tons (.048 MMT) per year are currently incinerated off-site by four firms. Full capacity is being utilized (100%). Considering 2-3 month backlogs, it can be said that demand currently exceeds supply. Furthermore, with accelerated voluntary phaseout of capacitors and transformers containing PCBs occurring, demand could exceed supply by as much as 3-4 times.

Waste quantities currently managed under other land disposal practices are estimated as:

	Split:		Total Quantity of Waste Managed (MMT/year):	
Management Practice	On-site/Off-site		On-site	Off-site
-Landfills	30%	70%	0.95	2.22
-Injection Wells	97.5%	2.5%	31.1	0.8
-Disposal Impoundments	95%	5%	18.06	0.95

3. Projected Changes in Incineration Demand and Capacity Utilization

Commercial incineration firms forecast a growing market for their services over the next three to five years, even in the absence of any regulatory changes. These firms estimate that demand for incineration could increase from 5 to 20 percent, primarily due to:

- Increased demand for PCB incineration capacity as voluntary phasing out of PCB-contaminated products accelerates.
- Possible lack of availability of on-site incineration capacity based on the assumption by commercial firms that few generators can and/or desire to go through the complex regulatory process, and absorb the costs and possible delays involved in expanding their capacity.
- Lack of availability of competitive alternative technologies to significantly affect the market for incineration over the next five years. (See Section B on Assessment of Emerging Alternative Technologies.)
- Declining net landfill capacity resulting from site closures and slow addition of new landfills.
- Added volumes of Superfund wastes resulting from ongoing clean-up activities.
- Generators' increasing concerns over the liabilities of land disposing wastes as opposed to incinerating them.

The projections of market growth if RCRA regulatory changes are implemented show that significant additional quantities of wastes would become available. This would result in an increased demand over the short to mid-term, with on-site and commercial incineration unable to meet demand. It is speculated that the degree to which commercial facilities can meet the increased demand depends primarily on their ability to bring new facilities on-line and the speed with which regulatory changes are enacted.

The effect of regulatory restrictions on on-site and commercial incineration (using the mid-range or average case) is estimated for four regulatory scenarios. The scenarios are assumed to be implemented immediately, and it is assumed that current incineration capacity does not increase.

It is also assumed that, of the additional wastes that become available for incineration due to the regulatory restrictions, a proportionally larger percentage of these wastes would move into the commercial incineration market rather than remaining on-site to be incinerated or otherwise managed. This is based on the presumption that, on the margin, most generators would elect to have commercial facilities incinerate their additional wastes rather than expand their own capacity.

Excess of Demand Over Existing Incineration
Capacity (expressed as a % of current capacity)

Regulatory Scenario	On-site	Off-site
-Landfill Restrictions	40%	215%
-Deep Well Injection Restrictions	54%	306%
-Disposal Impoundments Prohibitions	52%	288%
-Waste-In-Boilers Restrictions	42%	106%

Additional listings of hazardous wastes and lowering the small generator exemption could have further effects on the demand for incineration; however these are not projected in the analysis.

4. Projected Changes in Available LOHW Commercial Incineration Capacity

The availability of additional land-based or ocean capacity is seen to offer some moderation of the capacity shortfalls anticipated, depending on how rapidly this capacity is added to the commercial market. Current LOHW incineration capacity could increase from using currently available, but unused land-based incineration capacity, and from altering waste feeds to burn less solids/sludges and more liquids. Capacity could also increase by making three existing incinerator ships available. (They have a combined capacity of 247,000 metric tons/year, as compared to approximately 250,000 metric tons/year from existing land-based capacity.)

5. Implications of the Market Analysis

Using the projections of excess demand for commercial incineration created by the four regulatory changes, estimations of incinerator equivalents that would be required in order to meet such demand can be drawn. Such projected excess demand could be met by either 82 additional land-based incinerators (20,000 metric ton per year average capacity), or 33 additional incinerator ships (50,000 metric ton per year average capacity).

This type of projection is highly subjective because it depends upon two key factors which are open to debate: 1) the response of LOHW generators to the restrictions in terms of either developing additional on-site LOHW management capacity or relying on the commercial market, and 2) the policies of EPA in phasing in the new restrictions, encouraging the development of other waste management alternatives, and creating incentives or barriers to onsite versus commercial incineration.

We conclude that although current commercial and on-site hazardous waste incineration capacities on land are adequate to handle existing demand (except for PCBs), future demand will significantly exceed this capacity as other disposal alternatives are increasingly restricted. However, it cannot be predicted with accuracy how much additional commercial capacity will be required.

B. ASSESSMENT OF EMERGING ALTERNATIVE TECHNOLOGIES

This section reviews available information on technologies, both existing and new, that offer suitable alternatives to conventional incineration of liquid hazardous wastes.* Existing and emerging alternative thermal, chemical and biological processes for the treatment or destruction of liquid hazardous wastes are reviewed in order to address three questions:

1) What technologies other than incineration are now available, or may be in the near future, to treat, destroy or recycle combustible liquid hazardous waste?

2) What is the likely commercialization rate of each of these technologies?

3) How do these technologies compare to incineration in terms of cost, capability, benefits, and environmental and human health impacts?

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*Conventional incineration processes include land-based, ocean and improved incineration technologies, such as fluidized bed incinerators or mobile incinerators.

The processes reviewed are those that currently exist, or may exist in the next five years. They are not incineration processes, but can be used to treat or destroy the same types of liquid organic waste streams that are presently destroyed in incinerators. Existing alternative technologies are defined as those processes other than conventional incineration that are in existence today, are suitable for treating or destroying liquid hazardous waste streams, and are available for commercial use. Emerging alternative technologies are innovative processes that are suitable for treating or destroying liquid hazardous waste streams, but have not yet been adopted for commercial use.

Each alternative technology is described and discussed in terms of the types of waste the system is capable of accepting, throughput/capacity of the process, operational cost, anticipated environmental impact, and anticipated date of commercialization (for emerging technologies).

Only existing and emerging thermal processes were determined to be potential alternatives to conventional incineration. Theoretically, liquid organic hazardous waste streams can be treated in various thermal, chemical and biological processes, however, no significant use of biological or chemical treatment for combustible liquid hazardous waste is anticipated in the forseeable future. Many biological processes are only in the initial stages of development and their potential environmental impacts are numerous and hard to predict. There are also several barriers to the application of chemical processes, including cost, environmental considerations and the fact that combustible liquid hazardous wastes are generally bad candidates for chemical treatment.

1. Existing Alternative Technologies

The existing thermal alternatives believed to be most suitable are industrial processes (cement kilns, lime kilns and aggregate kilns) and co-combustion in industrial boilers. These are summarized in Chart A. Currently, substantially more hazardous waste is burned in industrial boilers than in incinerators.

2. Emerging Alternative Technologies

Currently, there are many new processes in various stages of development for treating and destroying all types of hazardous wastes. The processes discussed are compiled from responses to two national solicitations for new hazardous waste treatment ideas, from several literature reviews, and through contact with experts in the field.

CHART A
EXISTING ALTERNATIVE TECHNOLOGIES

Technology and Description	Suitable Wastes	Capacity Per Unit of Time	Cost Per Unit of Waste	Environmental Effects Data	Commercial Status
HAZARDOUS WASTE DISPOSAL IN INDUSTRIAL PROCESSES: - waste supplements primary fossil fuel to fire kilns - high temperatures and long residence destroy wastes	depends on industrial process candidate waste streams include: waste solvents, bottonms from solvent reclamation operations, and paint residues	1000 - 25,000 gallons/day depending on kiln size and percent of fuel replaced by waste	zero (if company accepts high energy waste for its fuel value) to 20-25 cents/ gallon	will be regulated to meet standards similar to those for incineration	currently used commercially .35 million tons of waste destroyed in 1981
INCINERATION IN POWER BOILERS: Agency is now in process of regulating	1% - 3% halogenated liquid organic waste stream	depends on the size of the boiler	specific cost figures not available minimal cost assumed becuase cause most boilers are on-site and act as substitutes for incinerators	EPA supports research to determine emissions data shows boilers have DREs comparable to incineration.	widely used because of regulatory exemption and energy recovery 3.5 million tons processed in 1981 by 1300 boilers

Twenty-five emerging technologies were considered for inclusion in the report using the following criteria:

1) Is the process designed for a liquid organic waste stream?

2) Is the process at the developmental stage to be available within five years?

3) Is the process innovative, or is the process just a modification of conventional incineration technology?

Only a few of the processes reviewed met all three criteria and thus were determined relevant to this study. Those emerging processes selected for further consideration in this study are:

- High Temperature Electric Reactor
- Molten Salt Reactor
- Plasma Arc
- Wet Air Oxidation
- Supercritical Water
- Molten Glass Incineration

These processes are summarized in Chart B. It should be noted that not all of these alternatives are able to destroy the full range of wastes handled by conventional incinerators. However, for the purpose of this study, candidate waste streams for treatment by emerging alternative technologies were identified based on EPA data that they represent the highest volumes of waste incinerated in the United States in 1981.

3. Existing and Emerging Alternative Technologies versus Conventional Incineration

Although all of the existing and emerging technologies reviewed are capable of processing the types of liquid hazardous wastes in question, the technologies vary in terms of cost, throughput capacity and potential environmental impact.

Based upon the information obtained in the surveys, existing alternative technologies may provide cost advantages compared to conventional incineration. However, the lack of reliable cost figures for all of the alternative processes should be noted. The report indicates that:

- The reclamation of energy value in existing alternative processes (industrial kilns and power boilers) reduces their overall costs to a level below that of incineration. Also, the use of existing facilities lowers capital investment.

CHART B

EMERGING ALTERNATIVE TECHNOLOGIES

Technology and Description	Suitable Wastes	Capacity Per Unit of Time	Cost Per Unit of Waste	Environmental Data	Commercial Status
WET AIR OXIDATION:					
- process of oxidizing organic compounds in water at temperatures of 350° to 650° F.	very dilute organic and inorganic aqueous waste except highly refractory organics	10 gallons per minute	5 to 10 cents a gallon for a 10 gallon system costs for larger system not available	limited data available EPA currently evaluating a unit on cyanide, sulfides and non-halogenated waste	technology currently available widespread use expected in next 2 years on aqueous waste
MOLTEN GLASS INCINERATION:					
- high temperature in furnace (2300°F) destroys organic waste streams - combustion gasses pass through ceramic filters - glass slag encapsulates inorganic residues	any combustible waste degree of halogenation not a consideration scrubbers required for HCL	existing glass manufacturing process 100 - 21,000 lbs per hour	cost figures not available	data not available testing needed ceramic tiles and residue encapsulation in slag indicate minimal impact	not reported
SUPERCRITICAL WATER:					
- inorganics, insoluble in supercritical water, are removed from waste streams - organics rapidly oxidized	aqueous waste streams with high levels of inorganices and toxic organics treatment of highly halogenated material not yet demontstrated	currently treats 1000 - 2000 gallons per day	cost figures not available	bench-scale test on various wastes indicates DREs of 98.5% - 99/8%	commercial scale units will be available in 1 - 3 years

CHART B

EMERGING ALTERNATIVE TECHNOLOGIES (continued)

Technology and Description	Suitable Wastes	Capacity Per Unit of Time	Cost Per Unit of Waste	Environmental Data	Commercial Status
HIGH TEMPERATURE ELECTRIC REACTOR: - two companies: Thagard Reaseach Huber Corporation - vertical reactor heated by electrodes implanted in the walls to pyrolize organic wastes	process initially designed for solid waste also suitable for liquid refractory waste streams	75 - 125 lbs of solids per hour no figures available for liquids, but it is assumed throughput would be less	cost information not avilable Huber claims cost comparable to conventional incineration	DREs far in excess of the 99.99% RCRA requirement	mid-summer 1985
MOLTEN SALT REACTOR: - burning and scrubing (900°C) oxidize carbons of organic matter to carbon dioxide and water - byproducts (phosphorous, arsenic, sulfer, halogens) retained in melt as inorganic salt	designed for solid and liquid waste especially applicable to highly toxic and halogenated combustible waste with low percentage of ash	pilot scale facility processes 80 to 200 lbs per hour	cost data not available	no emissions organic salts are the only biproduct DREs for organics, pesticides & chemical warfare agents 99.99% to 99.99999%	currently available for commercial use but none operating on that scale to date
PLASMA ARC: - uses the high temperature of plasma (50,000F) to destroy hazardous waste - all hardware in 45 foot mobile trailer	highly toxic liquid waste streams degree of halogenation not a consideration	600 lbs. per hour in commercially sized unit	cost data not available	current demonstration in New York state will provide info on DREs and emissions	commercial scale unit to be operating in 1 to 3 years

- The costs for the emerging processes Wet Air Oxidation, High Temperature Electric Reactor and Molten Salt appear at least comparable to conventional incineration.

- The costs of Supercritical Water, Plasma Arc and Molten Glass will probably exceed incineration. However, each of these technologies may offer advantages over conventional incineration processes for specific waste streams that could justify the higher costs.

Existing alternative technologies are capable of treating, recycling or disposing of significant amounts of liquid hazardous wastes. The Agency is now developing standards for these processes similar to those for hazardous waste incinerators. The potential market impact of these standards was addressed earlier in this chapter.

Emerging alternative technologies will have a minimal impact on the liquid hazardous waste load currently destroyed in conventional processes. Although all of the emerging processes evaluated offer some technical advantages, their commercial adoption will not significantly affect the market for conventional incineration. It is expected that these processes will only be used on the most toxic wastes, representing only 2% to 3% of the liquid combustible waste streams.

More testing will be needed to determine the environmental effects of both existing and emerging alternative technologies.

- The environmental effects of the existing alternative technologies are currently being assessed. RCRA regulations are being proposed for industrial boilers to assure that their operating performance is protective of human health and the environment.

- The environmental impacts of most emerging alternative technologies have not been tested. In many cases, their effects are expected to be roughly comparable to those of conventional incineration.

VI. COMPARISON OF RISKS FROM LAND-BASED AND OCEAN-BASED INCINERATION

This chapter presents a summary of the comparative risk assessment. The work was performed under contract and directed by EPA's Office of Policy Analysis (OPA). OPA worked with Industrial Economics, Incorprated (IEc) to develop a comparative assessment of the risks posed by land-based and ocean-based incineration systems.

Due to the complex, cross-program nature of the task, this work has been extensively reviewed by experts throughout the Agency. Substantial assistance in reviewing the methodology and substance of the study was provided by the following offices:

The Office of Research and Development,
The Office of Water,
The Office of Solid Waste,
The Office of Toxic Substances,
The Office of Air, Noise, and Radiation, and
EPA Regions II, III, IV, V, and VI.

In addition, the U.S. Department of Transportation, including the Coast Guard, provided a detailed review and substantial assistance in the analysis of transportation releases.

Ocean and land-based incineration systems have different physical characteristics and affect different locations and ecosystems. As a result, structuring a consistent comparison is difficult. This report integrates existing information and adds new analyses developed using existing methods and data. No new primary research has been completed. While the analysis will assist efforts to evaluate incineration and other technologies for hazardous waste management, it is important to understand that the results of this effort are not sufficient to determine the advisability of any specific land-based or ocean incineration proposal.

This chapter is divided into four major sections. The first section alerts the reader to limitations of this study in terms of the scope of its coverage and uncertainties in the methods and data used. Section B identifies the key elements of the case study employed. It provides a description of and rationale for the incineration system components and waste streams selected.

The final two sections present the heart of the analysis. Section C describes the quantities and locations of potential releases for all aspects of the incineration systems, including transportation and handling. Probabilities are calculated for releases due to accidents, spills, or other infrequent events. Section D addresses the potential human health and environmental impacts for the various types and locations of releases.

A. LIMITATIONS OF THE STUDY

All of our analyses are subject to many limitations and caveats due to uncertainties in the data and methods that were used. These limitations and caveats are explained fully in the chapters and appendices of this report. All of our results should be interpreted with caution, and with a complete understanding of all of these limitations. Some of the general limitations of the analyses are described below.

1. By design this analysis is limited to considering only incineration systems. It does not consider potential environmental or economic risks or benefits from use of other methods of hazardous waste treatment, storage or disposal.

2. The analyses reported here are applicable only to the specific land- and ocean-based cases examined. Results for other locations, wastes and technologies could vary substantially.

3. We have attempted to structure incineration systems and wastes typical of actual or likely practice so as to generate an expected rather than a best or worst case analysis. However, data limitations have required use of many conservative assumptions in our estimates of release quantities, and the methods for estimating effects of releases generally err on the side of overestimation. Thus, our overall results overestimate releases and resulting effects.

4. We have not considered a number of effects which might result from releases from the ocean- and land-based systems. In particular, we have not analyzed the possible effects of releases on terrestrial ecosystems.

5. Our analysis of the quantity of and effects from stack releases for both systems is based on assumptions about incinerator and scrubber performance and waste composition, and on results from EPA-sponsored trial burns. The data on PIC generation developed from the trial burns is extremely uncertain and subject to debate. This limitation may be overcome in the future as more and better data become available.

6. The estimates of the effects of spills into the marine environment system releases assume that no mitigating activities are completed.

In view of the above, the absolute release and effects estimates for land- and ocean-based systems are less meaningful than the relative differences shown between the two systems. Our results are particularly sensitive to factors (such as PIC emissions, scrubber efficiency, and so forth) that alter the relative performance of the two systems considered.

B. INCINERATION SYSTEMS CONSIDERED

1. Incineration System Components

We separate land- and ocean-based incineration systems into three and four separate physical components, respectively. Both land- and ocean-based systems include:

- Land Transportation: transport of wastes by truck from the generator site to the incinerator or pier,
- Transfer and Storage: transfer and storage operations at the land-based incinerator, pier, or other storage facilities, and
- Incineration: incineration of the waste.

In addition to these steps, ocean-based incineration systems include:

- Ocean Transportation: transport of the wastes by ship from the pier facility to the burn zone.

At each of these stages, wastes and hazardous by-products (for example, volatilized fractions or products of incomplete combustion) can be released to the environment. The nature of these releases varies from relatively unlikely releases of large quantities of waste (such as spills from truck or ship accidents) to very likely releases of smaller quantities of waste (such as stack emissions, minor pump leaks, and so forth). We attempt to quantify losses from all of these possible release points.

Our analysis is a case study of one land and one ocean-based system which are similar to existing systems, but are not exact duplicates of them. The system elements are detailed in Table 1. The ocean-based system is similar to that proposed by Chemical Waste Management, Inc. (CWM), to operate the Vulcanus II from Mobile, Alabama to the Gulf of Mexico burn zone. However, we assume that an integrated storage and transfer facility is located at the port. Our land-based system is not based on any single incinerator but combines characteristics of several facilities.

As Table 1 shows, land transportation assumptions for the ocean- and land-based systems are similar. We assume that wastes are transported 250 miles from generator to land-based incinerator or pier. Tank trucks are the assumed mode of land transport in both cases; and weather, road, and other driving conditions are assumed to be "average." While wastes destined for land- or ocean-based systems might travel different distances, changes in the 250 mile trip length do not alter our results significantly.

Transfer and storage characteristics for each case are assumed to be similar and are determined primarily by the configuration of equipment used for handling and storing wastes. Ocean-based incineration requires one extra loading step -- pumping wastes from an onshore storage facility or from tank trucks through a fixed piping system into the incinerator ship. The type of storage tanks used also is critical, since the emission characteristics of alternate tanks differ greatly. Our analysis considers both accidental spills during transfer and storage and continuous "fugitive" losses from storage tank vents, pump seals, and so forth. We have not considered releases from major accidents involving fire or explosion at storage facilities. The probability of such events occurring is very low and, because both land- and ocean-based systems require similar storage facilities, the potential for events of this type would be about the same for each system.

Ocean transportation characteristics are unique to the ocean-based system, and have been drawn directly from CWM's proposed plan for operations through Mobile Harbor from Chickasaw, Alabama. These operations will require an 800 kilometer transit through Mobile Harbor, across the continental shelf near the mouth of the Mississippi River, and on to the burn zone.

Finally, Table 1 shows the assumed characteristics of the incinerators themselves. Both land-based and ocean-based incinerators are assumed to be liquid injection units with capacities up to 70,000 metric tons per year. This capacity was selected based on the characteristics of the Vulcanus II. Although this capacity is greater than any commercial land-based facility, incinerators of this size are feasible and in operation at some on-site facilities. Consistent with current practice the land-based unit is assumed to employ scrubbers, while the ocean-based unit does not. We assume that these units achieve destruction and removal efficiencies (DRE) of 99.99 to 99.9999 percent depending on the waste burned. In effect, we assume that either system will meet current permit requirements concerning DRE and other operating parameters.

Table 1

SUMMARY OF INCINERATION SYSTEM COMPONENTS

Component	Ocean-based System	Land-based System
Land Transportation	Tank trucks (5000 gallons)	Tank trucks (5000 gallons)
	250 miles	250 miles
	"Average" weather, roads, etc.	"Average" weather, roads, etc.
Transfer and Storage	Storage at pier in two floating-roof tanks.	Storage at incinerator in two floating-roof tanks.
	One truck unload.	One truck unload.
	One load to vessel.	N.A.
Ocean Transportation	800 km (500 miles) to burn zone.	None.
	Specific path from Mobile to zone.	
	Vessel specifications and operations plan as per CWM for Vulcanus II.	
Incineration	Liquid injection, no scrubber.	Liquid injection with scrubber.
	DE = 99.99 percent or 99.9999 percent for PCBs.	DRE = 99.99 percent or 99.9999 percent for PCBs.
	Throughput to 70,000 MT/year.	Throughput to 70,000 MT/year.

2. Waste Streams

The environmental transport of wastes and by-products and their ultimate fate and effects depend strongly on the precise composition of the mixture released. In general, adequate data do not exist to predict the transport, fate and effects of mixtures released to the environment. In view of this, we assume two "simplified" waste streams with single hazardous constituents in this analysis.

1. A waste containing 35 percent by weight of polychlorinated biphenyls (PCBs). Arochlor 1254 is assumed to be the specific PCB, and the remaining 65 percent of the waste stream is assumed to be non-hazardous. Each system is assumed to burn 56,000 metric tons of this waste stream each year, based on historical burn rates for PCB wastes.

2. A waste containing 50 percent by weight of ethylene dichloride (EDC) and 50 percent non-hazardous substances. Each system is assumed to burn 68,400 metric tons of this waste stream each year, based on historical burn rates for similar chlorinated organic wastes.

In addition, each waste stream is assumed to include 100 ppm each of arsenic, cadmium, chromium and nickel. These metals are among those specifically limited in the Agency's proposed regulation for ocean-based incineration, and each has been designated a human carcinogen by EPA's Carcinogen Assessment Group. Although all four have been found in a variety of actual waste streams, it is likely that our assumption overstates the average concentration of carcinogenic metals in incinerable wastes.

Commercial incinerators handle many waste streams of varying composition. Four considerations caused us to assume the simplified wastes described above. First, CWM has requested a permit to burn PCB-containing wastes and thus the possible release, transport and effects of these compounds are of particular interest to EPA. Second, EDC is a common component in many hazardous waste streams currently incinerated and is typical of a large volume of wastes generated by the organic chemicals industry. Third, the physical characteristics and resulting transport behavior of PCBs and EDC in the marine environment are quite different, illustrating how fundamentally different waste components might behave. Fourth, human cancer potency factors are available for both PCBs and EDC and information is available on the toxic and bioaccumulative effects of the materials in marine organisms.

C. POTENTIAL RELEASES

1. Overview of Potential Release Quantities

Tables 2 and 3 present our estimates of the "expected" annual average release quantities from ocean-based and land-based incineration for the PCB and EDC wastes, respectively. For releases due to accidents, spills and other infrequent events, these estimates represent the long-term average release, which includes years with no release and years with one or more releasing events. As a result, actual releases in any single year for these events could range from zero to relatively large quantities if, for example, a truck is involved in an accident that results in a spill. Our calculation of expected quantities released is a statistical artifact which accounts for both the probability of a release and the resulting magnitude of waste lost. Annual averages are used primarily for comparative purposes. They enable us, for example, to compare releases over the course of a year from incinerator emissions with a highly improbable but potential one-time event such as a spill due to an accident at sea.

Each table shows the expected quantity of release for each component of the land- and ocean-based systems. All figures have been rounded to the nearest 100 kilograms (0.1 metric tons). For convenience, a subtotal is provided for releases from transport and handling steps and for incinerator stack releases. Metals included in scrubber effluent are also reported.

Overall, comparison of the expected releases from the ocean-based versus the land-based systems for these two wastes shows that expected release quantities from the transportation and handling components range to roughly 15 percent of the long-term average release expected. The extra transport and handling steps required by ocean-based systems do not add significantly to the long-term expected release, but they do create the remote possibility of a major accident and subsequent release of waste.

Incineration itself accounts for the major release of wastes and hazardous by-products for both wastes and systems considered. The quantities released by incineration are a function of assumptions about metals content and the performance of the incinerator and scrubber. Available estimates of PIC generation are very uncertain. Releases from each component are further discussed below. While expected annual releases in the 25 to 50 ton range may appear large in the abstract, such releases are very small when compared to many industrial operations, such as power plants burning fossil fuels.

Table 2

SUMMARY OF EXPECTED QUANTITIES RELEASED PER YEAR*
PCB Waste
(metric tons per year)

Release Point	Ocean-based System	Land-based System
Land Transportation	2.1	2.1
Transfer and Storage	1.2	1.1
Ocean Transportation	0.6	--
Subtotal	3.9	3.2
Incineration		
Undestroyed Waste	0.1	0.1
PICs	0.0	0.0
Metals	22.4	4.5
Subtotal (Stack)	22.5	4.6
Scrubber Effluent Metals	--	17.9
Total Organics and Metals**	26.4	25.7

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* For releases due to accidents, spills, and other uncertain events, these estimates represent the long-term average release which includes years with no release and years with one or more releasing events.

** When these total releases are compared to the 56,000 metric tons of PCBs incinerated per year in this case study, the release per metric ton incinerated is about 0.0005 metric ton for each system.

Table 3

SUMMARY OF EXPECTED QUANTITIES RELEASED PER YEAR *
EDC Waste
(metric tons per year)

Release Point	Ocean-based System	Land-based System
Land Transportation	2.7	2.7
Transfer and Storage	1.2	1.1
Ocean Transportation	0.8	---
Subtotal	4.7	3.8
Incineration		
Undestroyed Wastes	6.8	6.8
PICs	20.6	0.6
Metals	27.4	5.5
Subtotal (Stack)	54.8	12.9
Scrubber Effluent Metals	---	21.9
Total Organics and Metals**	59.5	38.6

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* For releases due to accidents, spills and other uncertain events these estimates represent the long-term average release which includes years with no release and years with one or more releasing events.

** When these total releases are compared to the 68,400 metric tons of EDC incinerated per year in this case study, the release per metric ton incinerated is about 0.0009 metric ton for the ocean-based system and about 0.0006 metric ton for the land-based system.

2. Land Transportation Releases

Tables 2 and 3 show that the expected release from land transportation will average 2.1 and 2.7 metric tons (MT) per year for the PCB and EDB wastes, respectively. Again, these estimates represent long-term averages. Releases in any year would vary from zero to larger quantities if a spill occurred. The slightly greater release estimated for the EDC waste reflects the larger quantity of this waste assumed to be handled by each system. Because land transportation has the same configuration in each system, there is no difference in the release quantities expected for the land- versus ocean-based system.

Our analysis of releases from land transportation considers two types of potential losses -- spills from vehicular accidents and spills from enroute container failures. We base our estimates of the frequency of such events and of the size of the resulting spills on data provided by the U.S. Department of Transportation (DOT). These data pertain to all tank trucks carrying hazardous materials. Use of the DOT data with our assumptions regarding miles travelled results in an expected .18 and .26 releasing vehicle accidents per year for the PCB and EDC wastes, respectively. The annual number of container failures is estimated at .23 and .32 for the PCB and EDC wastes. The average fraction of cargo released in vehicular accidents is about 40 percent. In contrast, spills from container failures typically release only about 4 percent of the cargo in the container.

Information supplied by hazardous waste services firms indicates that the DOT accident rates are higher than those experienced by these firms. This probably is due to management practices undertaken by such firms to reduce the probability of accidents and to their use of stainless steel tanks that are more resistant to rupture than are aluminum tanks. Thus, we believe that our analysis overestimates releases from land transportation. These estimates represent, on average, about 0.5 percent of the number of annual transportation-related releases of hazardous substances in EPA Region IV.

3. Transfer and Storage Releases

Our analysis of wastes released from transfer and storage considers three types of releases: spills when unloading wastes from tank trucks; spills from equipment at waste transfer and storage facilities; and fugitive emissions from transfer and storage. As shown in Tables 2 and 3, the expected quantity released from transfer and storage activities is slightly over one metric ton per year for both systems and waste streams considered. These release estimates are based on information developed by Arthur D. Little, Inc. and DOT.

Spills from the transfer and storage component are fairly infrequent events. They are estimated to occur at a rate of about 0.04 to 0.05 per year for the transfer of wastes from tank trucks and at a rate of about 0.03 to 0.04 per year for equipment and storage tanks. The ocean incineration system has one additional component -- the loading hose to transfer wastes to the ship. We estimate the rate of spills from the hose at about 0.002 to 0.003 per year, with the average spill size about 6 to 7 MT. It is likely that spills of this type would be contained either on the deck of the Vulcanus or by booms placed around the vessel during loading. Spills from truck unloading or from equipment or storage tanks are also likely to be contained in the facility. Fugitive emissions would account for about 0.6 to 0.7 MT per year of this amount. The number of spills expected from this component of land- or ocean-based incinerators would represent, on average, less than 0.1 percent of the number of spills of hazardous material likely from fixed facilities in EPA Region IV.

4. Ocean Transportation Releases

The ocean transportation component of ocean-based incineration is the only major component of the system that has no parallel in a land-based operation. Therefore, potential releases from ocean transportation are of special interest when comparing the relative risks of land- and ocean-based incineration systems.

Incineration ships have operated off the coast of Europe in the North Sea since 1972. About 320 voyages have been made and about 650,000 metric tons of hazardous waste have been incinerated. No casualties such as collisions, groundings, rammings, or fires have occurred, nor have there been any spills from loading these ships in port. Although a very good safety record has been established, the number of voyages completed is too small to be used directly in estimating statistically the probability of spills.

In view of this, EPA asked Engineering Computer Optecnomics, Inc. (ECO) to develop estimates of spill rates based on the worldwide historical record of tank ships of a similar size class. Spill rates were developed for three impact type accidents (collisions, groundings, and rammings) and for non-impact accidents (fires, explosions, structural failures, and capsizings). Spill rates were developed for four locations of interest -- pier and harbor, Mobile Bay, coastal area, and burn zone. Estimates were also developed of the percentage of spills likely to involve one, two, or three or more tanks -- 80 percent, 15 percent, and 5 percent, respectively.

The historical spill rates were adjusted to take into consideration the design of the Vulcanus (double hull, double bottom construction and the use of a controllable pitch propeller and bow thruster), operating restrictions to be imposed by the

Coast Guard (escorts by tug boats and a Coast Guard vessel, imposition of a 300 foot moving safety zone, and limitation of transits to daylight hours and in conditions of above average visibility), and the soft bottom conditions in the Gulf. The precise effect that these factors may have in reducing spill rates is difficult to determine. ECO's adjustments were based on published studies, observed differences in spill rates, kinetic energy levels likely for accidents in different locations, and professional judgment.

The expected annual releases of 0.6 MT for PCBs and of 0.8 MT for EDC shown in Tables 2 and 3 are relatively small and represent average releases expected over a very long time. Spills from the vessel would be very infrequent events. We estimate that the frequency of all spills for the Vulcanus is about one per 1,200 operating years. However, the frequency of spills estimated for any particular location is less. For example, the overall spill rate for the pier and harbor area is about one per 3,000 operating years; for Mobile Bay about one per 10,000 operating years; for the coastal area about one per 4,000 operating years; and for the burn zone about one per 6,000 operating years. These estimated spill rates are for all sizes of spills. Spills involving two or three or more tanks would be extremely unlikely events. For example, the estimated rate for spills in Mobile Bay involving two tanks is about one per 67,000 operating years, and about one per 200,000 operating years for spills in the Bay involving three or more tanks.

The preceding estimates of releases are conservative, in that we assume that any tank involved in a spill releases its entire contents and that the entire ship's cargo is released in accidents involving three or more tanks. In addition, the estimates do not reflect the effects that remedial actions may have in removing wastes from the marine environment. Hazardous waste operators are required to develop a contingency plan for handling spills as a condition of the permit. Efforts to contain and recover spills are most likely to be successful in enclosed areas or in shallow waters, such as the pier and harbor area and Mobile Bay. However, estimating the effectiveness of remedial actions was beyond the scope of this study.

The tonnage carried by the Vulcanus is small in comparison to commercial shipments of petroleum and hazardous substances in the Gulf area. For example, the cargo carried by the Vulcanus would be only about 0.01 percent of petroleum and hazardous substances transported annually in the Gulf area. Since the Vulcanus has a lower spill rate than other vessels, the potential releases from the Vulcanus are only about 0.002 percent of that from ongoing shipments of petroleum and hazardous substances in the Gulf area.

5. Incineration Releases

Incineration itself is the major release point in both systems. Metals account for the largest releases when burning the PCB waste, with undestroyed wastes providing a minor contribution. [1] Our estimates of undestroyed wastes for both systems assume 99.9999 percent destruction of the PCB waste stream. Our estimates of metals emissions result from our assumptions about metals concentrations in the waste. Metals are transferred to scrubber effluent in the land-based case by use of a scrubber which is assumed to remove from 50 to 90 percent of the four metals considered. Thus, stack emissions of organics and metals in the land case are about 20 percent of those predicted for the ocean-based case.

Tables 2 and 3 present the expected annual average release quantities for the incineration component of both systems. Total organics and metals released from incineration of the PCB wastes is 22.5 metric tons per year for both systems if one includes both stack releases and scrubber effluent. Total organics and metals released by the ocean-based incinerator for the EDC waste is more than 50 percent greater than that expected for the land-based case (54.8 MT compared to 34.8 MT). This difference is due primarily to the higher level of PIC release estimated for the ocean case.

Products of incomplete combustion (PICs) are not expected in significant quantities for the PCB waste based on EPA's trial burn data. However, the results of these trial burns are subject to large uncertainty and considerable debate because of the procedures used and the limited number of PIC compounds that were considered. Thus, our estimates of PIC emissions for the PCB waste (.000000006 metric ton per year and .00002 metric ton per year for the ocean and land cases, respectively) could be in error by many orders of magnitude. In addition, we do not know of any complete explanation for the lower level of PIC generation found for ocean-based PCB incineration and the higher level found for ocean incineration of general organic waste relative to incineration on land. Alternate estimates of PIC generation and the resulting human health effects are analyzed in later chapters and appendices of this report.

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[1] Note that if incinerated waste streams contain significantly less carcinogenic metals than we have assumed, the total quantity of stack emissions released from each system would drop dramatically. Further, releases from the transportation and transfer/storage components would become the major contributors to total release.

In addition to the compounds reported in these tables, we also analyzed the release of chlorine at incinerators in both systems and the disposition of the chlorine to the atmosphere and, for the land-based system, to scrubber effluent and sludge. Our results show that 10,505 and 25,034 metric tons of hydrochloric acid (HCl) will be released from the incineration of the PCB and EDC wastes, respectively. In the ocean case all HCl is released to the atmosphere. In the land-based case the scrubber captures 99 percent of the HCl and neutralizes it. Thus, most chlorine in the land case is disposed as scrubber sludge or effluent.

D. HUMAN HEALTH AND ENVIRONMENTAL EFFECTS FROM RELEASES

1. Human Health Effects From Stack Releases and Fugitive Air Emissions

Our analysis of human health risks estimates the incremental risk of developing cancer for a hypothetical "most exposed individual" (MEI) who resides at the location of the highest overall risk due to air concentrations resulting from incinerator stack and transfer/storage fugitive releases. For the land-based system, the location of the MEI is based on Census data. For the ocean-based system the MEI is assumed to reside at that point on the coast where modelled concentrations are highest, averaged over a year. These risk estimates assume 70 years of continuous exposure. In the ocean case different areas are affected by stack emissions (the coastline downwind from the burn zone) and transfer/storage fugitive releases (the area around the port), while for the land-based case the same area is affected. Our calculations of risk for the land-based system consider two alternative sites for the incinerator, in Texas and Arkansas.

We chose to estimate risks to the most exposed individual in order to assess the largest risks likely to be suffered by any person due to the releases considered. While we could have considered the average incremental risk across the entire human population affected by each system, this metric requires estimation of the total exposed population and all levels of exposure -- a difficult and controversial task given the long distances and persistence of some compounds considered here. In general, other risk analyses have found that average population risks range from one to four orders of magnitude lower than the risk to the MEI.

Table 4 presents the incremental risk of developing cancer for the most exposed individual due to releases from land- and ocean-based fugitive (transfer/storage) and stack releases. As shown, the incremental risks from land-based incineration releases are about three chances in one-hundred thousand for the locations and wastes considered. Virtually

Table 4

SUMMARY OF INCREMENTAL CANCER RISK TO MOST EXPOSED INDIVIDUAL FROM INCINERATOR RELEASES

	PCB Waste	EDC Waste
Ocean-based System*		
Stack (coastline)	6.37×10^{-7}	1.06×10^{-6}
Fugitives (port)	2.02×10^{-8}	4.97×10^{-10}
Land-based System (average of two sites)		
Stack	2.74×10^{-5}	3.14×10^{-5}
Fugitives	7.05×10^{-7}	1.69×10^{-8}
Total	2.81×10^{-5}	3.14×10^{-5}

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* The ocean system is not totalled because the releases are at different locations.

all of the incremental risk to the MEI is due to stack releases, with fugitive releases resulting in increased risks of less than one in a million. Incremental risks to the most exposed individual at the coastline for the ocean-based system range from one in one million to 6 in ten million. As shown, the risks from fugitives to the MEI near the port facility are less than two per hundred million.

The data and methods used to generate these incremental risk estimates are highly uncertain and tend to overestimate expected human health effects. Thus, the absolute risk levels indicated by these figures must be interpreted with caution. EPA has completed studies of incremental risks from other hazardous pollutant releases using similar methods with similar uncertainties and biases. For example, a recent study on toxic air pollutants found that, on average, individuals in the U.S. face incremental cancer risks of about 4 to 6 chances in ten thousand.2/ Using this estimate as the base for comparison, incremental risks to the persons most exposed by the incineration systems considered here would be one to three orders of magnitude lower.

Table 5 presents more detailed information concerning the sources of the incremental cancer risks for the incineration systems considered. This table reports the contribution of principal organic hazardous constituents (POHCs), PIC and metals emissions to the total incremental risks suffered by the MEI. For convenience, risks due to fugitive emissions from transfer and storage operations are not included in the figures in Table 5.

The estimates in Table 5 show the relative magnitudes of incremental risk caused by each stack component for both wastes and systems considered. As shown, POHC and PIC releases cause risks that are from one to five orders of magnitude less than risks from metals. Thus, metals account for from 90 percent to virtually all of the incremental risks calculated for stack emissions. (As noted earlier, however, it is likely that our assumptions overstate the average concentration of carcinogenic metals in liquid incinerable wastes.) Risks from POHC releases are less than 1 per billion for the ocean system and less than 2 per 10 million for the land system. Risks from PIC releases are less than 4 in one billion for the ocean system and less than 2 in 1 million for the land-based system. Thus, risks from both PICs and POHCs in each system are low.

Table 6 presents the ratio of the incremental risks from land-based versus the ocean-based stack releases. The figures in this table were calculated by dividing the land-based risk

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2/ EPA, "The Magnitude and Nature of The Air Toxics Problem in the United States," Draft Report, Office of Air and Radiation and Office of Policy, Planning and Evaluation, 1984.

Table 5

INCREMENTAL CANCER RISK TO MOST EXPOSED INDIVIDUAL BY TYPE OF STACK RELEASE

	PCB Waste	EDC Waste
Ocean-based System		
POHCs	1.45×10^{-10}	5.51×10^{-10}
PICs	1.68×10^{-12}	3.36×10^{-9}
Metals	6.37×10^{-7}	1.06×10^{-6}
Total Stack	6.37×10^{-7}	1.06×10^{-6}
Land-based System (average of two sites)		
POHCs	5.13×10^{-8}	1.43×10^{-7}
PICs	1.79×10^{-6}	2.59×10^{-8}
Metals	2.56×10^{-5}	3.12×10^{-5}
Total Stack	2.74×10^{-5}	3.14×10^{-5}

Table 6

RATIO OF INCREMENTAL CANCER RISK FOR LAND- VERSUS OCEAN-BASED INCINERATORS BY TYPE OF STACK RELEASE

	PCB Waste	EDC Waste
POHCs	354	260
PICs	1,070,000	8
Metals	40	29
Totals	43	29

estimates in Table 5 by those shown for the ocean-based system. Thus, the figures in Table 6 indicate the relative size of risks estimated for the land-based versus the ocean-based system considered. For example, Table 6 indicates that, for the PCB waste, land-based emissions create about 40 times more incremental risk to the MEI than do ocean-based emissions. For the EDC waste, the ratio of land to ocean risk is about 30.

Tables 5 and 6 show that, given our assumptions, there is roughly 30 to 40 times more incremental risk from metal released from land systems. Changes in the type and concentration of metals in the waste could reduce these risk estimates by several orders of magnitude but would not change the relative performance of the land and ocean systems. Different assumptions about the performance of the land-based scrubber in removing metals, or about the atmospheric transport of metals over the ocean could affect the relative performance of the two systems considered. While different assumptions could broaden or narrow the differences in metals risk, it is unlikely that ocean-based systems would generate more incremental risk than land-based systems.

These tables also show that the land-based system generates more incremental risk from POHC emissions, but that the risks are low from both systems. The transport behavior of PICs is similar to that of POHCs and thus, for similar quantities and toxicities of release, PIC risks should show the same ratios. However, our analysis of trial burn data indicates that land- and ocean-based systems can generate very different quantities of PICs.

EPA's trial burn data indicate wide variation in PICs generated by different incinerators from different waste streams. The results of these burns are subject to great uncertainty and considerable debate. For the PCB waste, our analysis uses a PIC generation rate for the ocean-based system that is 10,000 times lower than that used for land since this rate is derived from trial burn data. When combined with the additional advantage of the ocean-based system in being further from human populations, the land-based unit generates over 1 million times the risk of the ocean system for PICs. Thus, our relative estimates of PIC generation from the PCB waste would have to be in error by a factor of one million for the land and ocean systems to present equivalent risks from PICs. Again, note that the absolute risks estimated for PICs from both systems are very low.

Our assumption regarding the amount of PICs from EDC wastes is quite different. For this waste, trial burn data suggest that the ocean-based unit will generate about 30 times more PICs than the land system. Despite the ocean system's exposure advantage, this lowers its ratio of risk compared to the land system to a factor of 8. While changes in relative PIC generation that are greater than an order of magnitude could make PIC risks from land and ocean systems equivalent or show land systems to be safer, we believe that such changes are unlikely.

Although the absolute numbers reported in Tables 4 and 5 are uncertain and biased to overestimate incremental risks, the relative differences shown in Table 6 are more certain and would be altered only by changes in the relative performance of the ocean- and land-based systems. Overall these results generally indicate that the human health risks posed by either system are relatively low, with the risk from the ocean-based system about one to two orders of magnitude less than from the land-based system. This general result was expected, since the burn zone is about 200 kilometers distant from the coast, allowing residual emissions to disperse and to partly settle out before reaching land, and since the plume emitted during trial burns has never been detected at the shoreline.

Along with incremental risks due to inhalation of hazardous compounds, we also considered incremental risks due to ingestion of foods contaminated by wastes or hazardous by-products from ocean- and land-based stack emissions. Although data and methods in this area are extremely limited, we found insignificant incremental risks from this ingestion route of exposure.

2. Environmental Effects From Incinerator Stack Releases

In addition to the human health effects summarized above, we considered the possible environmental effects that might result from incinerator stack releases. For the ocean-based case, we asked Applied Science Associates, Inc. (ASA), to estimate the deposition of stack releases to the ocean surface, the transport of these materials in the water column and sediments and resulting effects on the marine ecosystem. ASA's analyses indicate that no measurable effect on the marine ecosystem is expected due to stack releases from the EDC waste. The analysis of the PCB waste is complicated by the persistence of the compound and by scientific uncertainty about the role of the ocean's surface (the "microlayer") in capturing and concentrating atmospheric pollutants and providing these materials to the marine ecosystem. Notwithstanding these uncertainties, ASA's analyses indicate that long-term continuous burning of the PCB waste at the levels assumed here would not result in a measurable effect on the marine ecosystem. Information developed on the background atmospheric flux of PCBs into the Gulf waters indicates that it would be about two to three orders of magnitude greater than that from incineration of PCBs.

We were unable to complete a similar analysis of the effects on terrestrial ecosystems caused by land-based stack releases. However we did consider the possible environmental effects from the release of scrubber effluent and sludges from the land-based system. Because discharge of scrubber effluent and sludge is regulated by the Clean Water Act and the Resource Conservation and Recovery Act, respectively, disposal of these materials would have to be carried out in a manner approved by environmental permitting authorities. Thus, we assume environmental damage from these discharges is minor.

3. Human Health Effects From Ocean Transportation Releases

In addition to the effects from incinerator stack and fugitive releases, we also characterized possible human and environmental effects resulting from spills in the marine environment. Although the probability of a spill is very low, the magnitude of the resulting effects is of interest in public deliberations about ocean- versus land-based incineration systems. We considered the likely effects of release of cargo from the vessel at sites within Mobile Harbor, over the continental shelf on the path to the burn zone, and in the burn zone itself.

Table 7 presents information about the potential for human health consequences from loss of the entire vessel cargo. Volatilization of such a spill could expose human populations to high concentrations of hazardous constituents for short periods of time. Because of the acute nature of these exposures, we compared the estimated dosage received by human populations in the first 24 hours after a spill to the Threshold Limit Value (TLV) for PCBs and EDC. The TLV represents the dosage to which a worker can be exposed with no adverse health effects such as coughing, dizziness, and longer-term health damage. We adjusted the TLVs to account for continuous exposure rather than exposure for only eight hours per day. In all calculations we assume that the human population is directly downwind from the spill site and that the entire cargo of the vessel is released.

As shown in Table 7, we estimated the ratio of 24 hour dosages to adjusted TLV's for spills in Mobile Harbor at one and 15 kilometers from the city of Mobile, for spills over the continental shelf near the mouth of the Mississippi River, and for spills in the burn zone. The results show that spills of the entire cargo of either waste one kilometer from the city of Mobile could cause human health problems. Spills at the other locations are not expected to cause acute human health problems.

4. Environmental Effects From Ocean Transportation Releases

Table 8 presents a summary of the potential effects to the marine ecosystem from spills of half a tank in the three locations described previously. The ecosystem effects are summarized by changes in biomass levels and in bioconcentration levels for PCBs and EDC. For PCBs we considered both floating and sinking cases, since this compound, although heavier than water,

Table 7

SUMMARY OF HUMAN HEALTH EFFECTS FROM LOSS OF ENTIRE VESSEL*
(ratio of 24 hour dosage to adjusted TLV)

Release Location	PCB Waste	EDC Waste
Mobile Harbor		
1 Kilometer	1.3	1.9
15 Kilometers	0.06	0.12
Continental Shelf	0.019	0.002
Burn Zone	0.0019	0.0004

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* The probability of a spill involving three or more tanks of the vessel in any location is about one in 24,000 per year, and in the pier, harbor, and bay area is about one in 50,000 per year.

Table 8

SUMMARY OF MARINE ECOSYSTEM EFFECTS FROM SPILLS OF HALF A TANK

	PCB Waste		EDC Waste	
Release Location	Effect on Biomass	Bioconcentration Levels	Effect on Biomass	Bioconcentration Levels
Mobile Bay				
Floating Case	Small overall, severe reduction for benthos	3 to 5 orders of magnitude	Not Considered	Not Considered
Sinking Case	Uncertain	Uncertain	Minor	Minor
Continental Shelf				
Floating Case	Uncertain	Uncertain	Not Considered	Not Considered
Sinking Case	Small overall, substantial for benthos	2-3 orders of magnitude	Minor	Minor
Burn Zone				
Floating Case	Uncertain	Uncertain	Not Considered	Not Considered
Sinking Case	Minor overall, substantial for benthos	1-2 orders of magnitude for benthos and demersal fish	Minor	Minor

might float if entrained in lighter-than-water materials. For EDC, we consider only a sinking case, which results in rapid diffusion since this compound is soluble in water. We also modelled the effects of larger spills of 2 tanks and 8 tanks. As noted earlier, for modelling purposes we assumed no actions were undertaken to contain and remove the spill.

Table 8 indicates that EDC spills would have relatively minor effects on the marine ecosystem. These small impacts are the result of this compound's rapid diffusion to low concentration levels and its relatively low toxicity to marine species. In addition, bioconcentration of EDC is not a significant phenomenon. The same results hold for larger size spills.

In contrast, spills of PCBs are modelled to have major effects on the marine ecosystem. These effects range from being quite severe in the Bay (substantial reduction in benthic species and large bioconcentration effects on fish and shrimp) to less severe in the burn zone area. Since PCBs are a persistent compound, such effects are expected to last a long time. Bioconcentration effects in commercial and recreational species would be of most concern in the Bay and contaminated shelf areas. In the event of larger or smaller spills, the magnitude of bioconcentration effects is approximately linear with regard to quantity released.

Estimating the effects of spills of persistent compounds such as PCBs in the marine environment is an imprecise science at best. Because of substantial uncertainties regarding the long term fate of PCBs in the marine environment and the biological mechanisms involved in the food web, the results of the modelling effort should be viewed as a general indication of potential effects rather than as a precise measure of those effects.

VII. PUBLIC CONCERNS REGARDING INCINERATION

This section identifies and compares public concerns and objections to ocean and land-based incineration. The concerns described are based on a representative sample of those members of the public who have been most vocally opposed to, or at least concerned about, specific land-based and ocean incineration operations.

The information presented here summarizes information contained in the background document, "Public Concerns Regarding Ocean and Land-Based Incineration," prepared by the Office of Management Systems and Evaluation (OMSE). Information contained in the OMSE study is based on a review of public hearing transcripts, and on interviews with citizens, EPA regional officials, state officials, and incinerator companies.

It should be emphasized that the OMSE study is not an exhaustive survey of public opinion on incineration, but rather a study which catalogs the concerns reported by those citizens opposed to incineration, or at least worried about some aspects of it. Furthermore, these concerns were documented in the summer of 1984, and primarily reflect opponents' concerns from that time and earlier. Since that time, EPA has taken a number of actions to address many of the public's concerns about ocean incineration. We have issued proposed regulations, developed a comprehensive research strategy, and gathered more information, particularly on comparative risk, through this Agency-wide study. Nevertheless, it is still important to document citizens' concerns in this important area of public policy.

A. HISTORY OF OPPOSITION

1. Incineration Facilities Studied

For ocean incineration, there are only two case histories to examine, and both companies involved have experienced public opposition. All of the Agency's permitting experience is with one company, Chemical Waste Management, Inc. A second company, At-Sea Incineration, Inc., has progressed to the stage of applying for a research burn permit and searching for a port site. This study examined public opposition to proposed permits for Chemical Waste Management, Inc., to burn in the Gulf of Mexico, and the proposed siting of a port facility by At-Sea Incineration, Inc., in the Newark, N.J. area.

For land-based incineration, there were a total of fourteen cases where there has been some degree of public opposition. Opposition tends to occur when public hearings are held on proposed RCRA permits or PCB approvals. At the time of our survey in 1984, public hearings had been held for about 24 land-based incinerator facility permits. Of the fourteen facilities experiencing some opposition, three were handling primarily on-site wastes, while eleven were commercial facilities for waste generated off-site. Ten of those cases were examined in more depth. These ten included the three on-site facilities, which were all proposed facilities, plus seven off-site facilities, of which three were proposed and four were existing facilities with interim status.

2. Parties Involved and Intensity of Opposition

For both ocean and land-based incinerators facilities, the core of opposition has come from local citizens. For both types of facilities, local opposition has included not only environmental groups but also broader-based civic associations and local government officials.

It is difficult to estimate the overall extent of local opposition to land-based incinerators. EPA regional officials report that in some cases a majority of local residents appeared to be opposed, while in others the opposition seemed to stem from a relatively small but highly vocal segment of the local population.

Opposition to ocean incineration has been more regional in scope, since an incinerator ship is perceived by many citizens to have multi-state impacts. Opposition to ocean incineration has also involved a significantly wider range of people, including congressmen and governors, farmworkers and fishermen, scientists and local residents, and land-based incinerator operators. While the major concerns of each group may differ somewhat, they seem united by their opposition to facilities that they believe would significantly harm their communities, jobs and lifestyles. Ocean incineration has also involved active opposition by some national environmental groups.

3. Impacts of Opposition to Land-Based Incineration

Regulations for land-based incinerators have been in place since 1981, but experience so far with implementing the program has been limited. Of the 200 existing incinerator facilities that have applied for RCRA operating permits, only 23 have been issued final permits as of February 1985. Only four new incinerator facilities have been issued final permits. For the fourteen incinerator facilities that have had public opposition, the general impact has been to delay the siting and permitting process, and may result in some facilities never becoming operational.

The ten case studies on land-based incinerators with public opposition showed the following site-specific differences:

- On-site facilities (i.e., those that accept waste generated on the same site) have experienced the least public opposition. In addition, on-site facilities have had the greatest degree of public acceptance when off-site waste was not brought in, the company had a favorable record, and the company provided other benefits to the community.
- New, off-site facilities (i.e., commercial incinerators that accept wastes generated elsewhere) have had the greatest public opposition. In many ways, this situation is analogous to that of ocean incineration, since all incinerator ships are essentially new, off-site facilities.
- For existing, off-site facilities, the amount of public opposition has varied, but has generally been highest when PCB approval is requested.

As EPA continues to issue permits for land-based incinerators, public opposition is likely to continue in a similar pattern, although opposition to existing facilities may decrease over time. When asked to suggest solutions to their concerns, the public by and large offered no final solution except to site the facility elsewhere (i.e., not in my backyard). However, many people also expressed the need to have better, more explicit criteria for making decisions on siting incinerators.

4. Impacts of Opposition to Ocean Incineration

Citizen opposition has had impacts on both the national regulatory program and on the local siting activities of the companies. A major impact nationally has been to persuade EPA to delay consideration of new operational permits until regulations and standards are promulgated. EPA has also delayed consideration of new research permits until the Agency has completed a comprehensive research strategy.

A second impact has been to make it difficult to obtain local approval to site port facilities for the storage and transfer of hazardous wastes. In Alabama, use of Chemical Waste Management's port site has been hampered because of local public opposition. A recent change in the local zoning ordinance now makes getting approval for storage of hazardous waste at that port more difficult, although loading of the ship from tanker trucks is not hampered. In New

Jersey, siting of a port facility by At-Sea Incineration has been delayed while the state develops siting criteria, and public opposition there may diminish the chances of siting a port facility in New Jersey.

Citizen opposition to ocean incineration has been more wide ranging and intense than opposition to land-based incineration. Due to the scope of citizens' concerns, some amount of opposition to ocean incineration is likely to continue. Solutions offered by the critics tend to focus on either strict regulations and explicit siting criteria, or abandoning the program and relying on existing alternative disposal/treatment methods such as land incineration. In either case, the public wants EPA to promote long-term solutions that it feels are more appropriate, such as waste recycling, reduction, and detoxification.

B. CONCERNS REPORTED BY CITIZENS WHO ARE OPPOSED TO (OR AT LEAST WORRIED ABOUT) INCINERATION

For ocean incineration, the two areas of concern cited most often by citizens are: (1) the potential risk, and related impacts on health and the environment, of spills on land and water from routine activities and catastrophic incidents; and (2) perceived poor management of the ocean incineration regulatory program by EPA in the past.

Many people concerned about ocean incineration are not completely against an ocean incineration program, but they do want significant safeguards and guarantees. As one Alabama resident summed up the situation: "In general, the concerns are not about the technology but about the management aspects. It's a people issue. It's a question of who's running the regulatory program and who's running the ships."

For land-based incineration, the concerns cited most often are: (1) the potential risk to human health from fugitive air emissions and stack emissions; and (2) the potential risk of spills on land from routine transport, storage and handling, and accompanying health and environmental impacts.

Table 1 provides a comparison of major concerns reported by citizens regarding ocean or land-based incineration.

C. KEY ISSUES AND FINDINGS

Analysis of public concerns regarding incineration has brought to light a number of underlying issues that may have been acting as barriers to the use of incineration as

TABLE 1: COMPARISON OF CONCERNS REPORTED BY CITIZENS IN OPINION SURVEY

OCEAN INCINERATION	LAND-BASED INCINERATION
• Risk of spills on land and water from routine transport, storage and handling, and accompanying health and environmental impacts.	• Risk of spills on land from routine transport storage and handling, and accompanying health and environmental impacts.
• Inadequate public participation in the siting and permitting process.	• Same.
• Insufficient state and federal resources for effective monitoring and enforcement of regulations.	• Same.
• Unsuitability of Gulf burn site and of port sites in Mobile and Newark.	• Unsuitability of incinerator sites.
• Lack of credibility of incinerator operators.	• Same.
• Uncertainties about incineration technology, and concern about level of environmental protection afforded by a 99.99 percent destruction efficiency	• Same.
• Adverse economic impacts on local fishing, tourism and property values.	• Adverse economic impacts on local property values and lack of increase in local employment.
• Inadequate local emergency response capability for accidents on land, and inadequate technology for cleanup of spills in ports and on open water.	• Inadequate local emergency response capability in the event of accidents.
• Risk to the marine environment from air emissions.	• Risk to human health from air emissions.
• The importation of outside wastes into local areas is inequitable.	• Same.
• Difficulty of enforcement and compliance monitoring and of environmental monitoring of long-term impacts on the ocean.	(Not reported for land.)
• Risk of catastrophic spills in ports and on open water.	(Not reported for land.)
• EPA's poor management of the regulatory program for ocean incineration.	(Not reported for land.)
• Regulatory controls are not stringent enough on scrubber requirements and other technical issues.	(Not reported for land.)
• Lack of a national strategy for managing hazardous waste in order to provide the basis for a decision to either promote or abandon ocean incineration.	(Not reported for land.)
• The ocean is a public resource which should receive special protection.	(Not reported for land.)
• Ocean incineration would inhibit development of better methods for managing hazardous waste.	(Not reported for land.)
(Not reported for ocean.)	• Nuisances such as noises, odors and eye-irritating gases.

a waste treatment/disposal method. These issues are discussed below in some detail, followed by overall findings.

1. Issue: Dissatisfaction with the Public Hearing Process

At the point in the regulatory process when public hearings are conducted for both ocean and land-based incinerator permits, EPA officials typically discover that they have very different perspectives and specific concerns than those voiced by the public at such hearings. This has led to misunderstandings and citizens' dissatisfaction with public hearings and with the permitting process in general.

In hearings on proposed permits, the primary focus of the EPA staff is on compliance of the proposed permit with regulations and performance standards. This is because EPA officials accomplish their jobs of protecting the environment and human health through the diligent application of regulations and standards.

The public, on the other hand, is often concerned about broader or nontechnical issues, such as site selection, enforcement plans and capability, company credibility, and potential health risks. Most of these issues are ones that either EPA believes were resolved prior to the proposed permits (e.g., that incineration is an environmentally sound technology), or that EPA has no jursidiction over, such as the siting of land-based incinerators. Likewise, the incinerator operator's past performance record, while of serious concern to EPA, does not preclude the granting of a permit as long as all conditions and requirements of the regulations are met.

Part of the problem is that each group has different expectations for public hearings on proposed permits. Federal and state regulatory agencies, and the company, expect to discuss technical issues, and are often perplexed by both the vehemence of public concern and the broad range of issues raised by citizens. Government regulatory officials have already carefully evaluated a company's proposal in terms of its adequacy in meeting technical and administrative requirements. Company officials, in turn, present technical studies to show that the proposed facility meets all regulations. In contrast, community opponents talk in terms of potential health risks, inequity of siting decisions, and adverse local economic impact. When EPA and the state agency respond only to technical and permit-specific issues, the public perceives the regulatory agencies as being biased in favor of the company and being generally inflexible and unresponsive.

The perspective of regulatory agencies and most incinerator operators is that they are doing as much or more than is necessary to comply with what is required by law. They believe that through the public comment and hearing process, citizens are given a fair chance to voice concerns and be heard. Regulatory agency staff also claim, however, that they are not able to respond to concerns that are not technical in nature or that go beyond the scope of the regulations, and that full application of regulatory restrictions is not sufficient in dealing with citizens' general fears about toxic pollutants.

In the case of ocean incineration, EPA focused its discussion at public hearings primarily on the performance capabilities of the technology and on the risks and impacts at the ocean burn site. But the public was concerned about cradle-to-grave regulation, the potential health risks, environmental and economic impacts outside the burn site, and the ability of regulatory agencies to adequately enforce its regulations. This difference in scope of concerns reflects a lack of understanding by citizens that the scope of permit hearings is limited to the proposed permit, that technical requirements for an incinerator permit reflect underlying concerns for protecting health, and that other activities such as transportation are controlled by a different set of regulations.

2. Issue: Siting Decisions

A number of issues relating to the siting of incineration facilities stand out as influencing public opposition. The siting process itself is a source of frustration. Comments from the public indicate that the siting process isn't clearly defined and that the public is left out of siting decisions. They feel that criteria for selecting sites do not exist or are rudimentary at best. Certain aspects of any site seem to inevitably generate opposition, such as the transport route of waste to the site, the proximity of the site to schools, residential areas, or recreational areas, and the prior existence and impact of industries or hazardous waste facilities in the area.

EPA officials point out that they are being unfairly criticized by the public for siting decisions, since EPA has no authority over the selection of sites for land incinerators or port facilities. However, EPA does select ocean burn sites for incinerator ships.

The underlying public concern regarding siting is the question of equity in the original siting decision: why should their community be chosen to bear such a large share of the potential environmental costs of modern industry? This is reflected by the common reaction of "not in my backyard".

3. Issue: Credibility of Government and Industry

Public trust or distrust of regulatory agencies and companies strongly influences the acceptability of incineration regulatory programs in general, and the siting of individual facilities specifically.

State and federal regulatory agencies are judged by the public according to their past record in enforcement, permitting, monitoring, inspection capability, and cleanup activities. The public believes that there is a lack of sufficient federal and state resources to maintain and expand effective permitting, monitoring and enforcement programs. This view is based on publicized budget cuts at federal and state levels, and on their perceptions of an inadequate past record of regulatory agencies in these areas. EPA's poor public image with opponents of ocean incineration largely resulted from their perception that the program was being managed in a very ad hoc manner.

Companies intending to incinerate hazardous waste have come under intense public scrutiny. Their credibility is measured by their past experience in the community, their expertise in managing hazardous waste, and their past performance and safety record. In general, there is a very low degree of public trust of incinerator operators. It is often felt that the companies do not provide the public with information that is accurate and readily available, thus creating the perception that the company is not dealing "openly" with the public.

4. Issue: Heightened Public Awareness of Hazardous Waste Problems

There are basic fears by the public of any activity associated with hazardous waste, and according to citizens interviewed, there is a general lack of readily available public information on issues of hazardous waste management other than through the news media. One of the major findings of a 1979 study by EPA* is that there has been a widespread increase in public opposition to the siting and operating of hazardous waste management facilities of any kind, and that this increase can be traced to the national publicity given to the hazardous waste problem. "This publicity", says the report, "is focused almost exclusively on the disastrous results of improper management of hazardous wastes. The public is therefore unable or unwilling to distinguish between patently improper sites for hazardous waste disposal...and properly managed sites."

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* "Siting of Hazardous Waste Management Facilities and Public Opposition," U.S. EPA SW-809, November 1979.

Public fears have been heightened by news of ocean oil spills, discoveries of illegal hazardous waste dumps, and contamination caused by leaking landfills and other shoddy hazardous waste disposal operations. These fears, which have been described by some companies as irrational or fears of the unknown, tend to act as a unifying force among much of the opposition.

5. Issue: Public Acceptability of Risks

A related issue is that of the level of risk acceptable to the public. Risk assessments show that risks from hazardous waste incineration do not pose a significant threat to the public and are considerably less than risks associated with common daily activities such as driving an automobile. However valid this may be, a segment of the public seems to be saying that any additional risks are unacceptable, especially when there is a probability, however minimal, of a catastrophic event occurring which could have serious environmental or health consequences.

In addition, people seem to accept risk more readily if it is imposed voluntarily rather than involuntarily. Thus citizens tend to accept the risks of driving a car or smoking cigarettes more easily than the risks of environmental pollution, even though the risks to health from driving cars is statistically higher than the risks from certain types of environmental pollution. In the case of incineration, the relatively low risks to health are not acceptable to some people because the risk-taking is perceived as not of their choosing and not under their control or influence.

The amount of risk "acceptable" to the public also varies according to the amount of perceived community benefit from the incinerator facility. With some exceptions, off-site commercial incinerator companies are generally unknown to the local community, or, if known, may be associated with problems at their facilities in other communities. In contrast to local manufacturing businesses, the community envisions few benefits from a proposed commercial incinerator facility: a few jobs and perhaps some tax revenues. In contrast, potential risks are often seen as overwhelming: polluted air or water supplies threatening the entire community, decades of uncertainty, and hundreds of trucks carrying thousands of drums of hazardous waste on local roads. When local communities perceive the risks to be great and the benefits small, they tend to demand that the probability of something going wrong be low, or more often, nonexistent.

6. Issue: Need to Protect the Ocean as a "Public Resource"

Many citizens view the ocean as a public resource that must be protected, rather than as a handy dumping area which is "out of sight, out of mind." In other words, the ocean is perceived to be everybody's backyard rather than nobody's backyard. Consequently, ocean incineration has gained the status of a national issue.

7. Issue: Need for Link between Incineration Regulation and a National Hazardous Waste Management Strategy

Another issue unique to ocean incineration was the request from citizens and state officials that EPA develop and/or communicate a national hazardous waste strategy that provides a framework for either promoting or abandoning ocean incineration as a viable and environmentally sound technology.

8. Overall Findings

The overall findings of this study of public concerns suggest that ocean incineration has given rise to a greater degree of public opposition than most land-based incinerator operations (either proposed or existing). This is primarily because the perceived impact of land-based incineration is very localized, whereas ocean incineration is felt by some citizens to potentially affect an entire region: the port community, all the communities along the coastline near the burn site, and the marine environment. However, some off-site land-based operations, which have many characteristics in common with ocean incineration, have also received substantial opposition.

The findings also suggest that for land-based incineration, on-site facilities that directly serve a single waste generator have greater public acceptance than off-site, commercial facilities that serve multiple generators in a large market area. This is because people feel that off-site facilities do not provide sufficient economic benefits to the local community to offset the risks associated with importing wastes from other areas. On-site facilities are perceived as linked to businesses that are important to the local economy, and are generally not perceived as importers of hazardous waste.

Public opposition to incineration on both ocean and land may be reduced somewhat if regulatory agencies more fully address public concerns regarding basic regulatory policy and strategy, enforcement resources, local community impacts, equity of facility siting, and public decision-making processes. In large part this is a matter of taking the time and effort to better inform the public about the "big picture" (i.e., the Agency's overall regulatory policy, strategy, and activities for hazardous waste management), in order to provide a context for discussions of permits or siting decisions for individual incinerator facilities. The fact that EPA has a national hazardous waste management strategy to encourage long-term solutions is not very helpful if the public does not know about it. Improved communication and more visible leadership from EPA would go a long way toward resolving many of the issues and public concerns discussed here.